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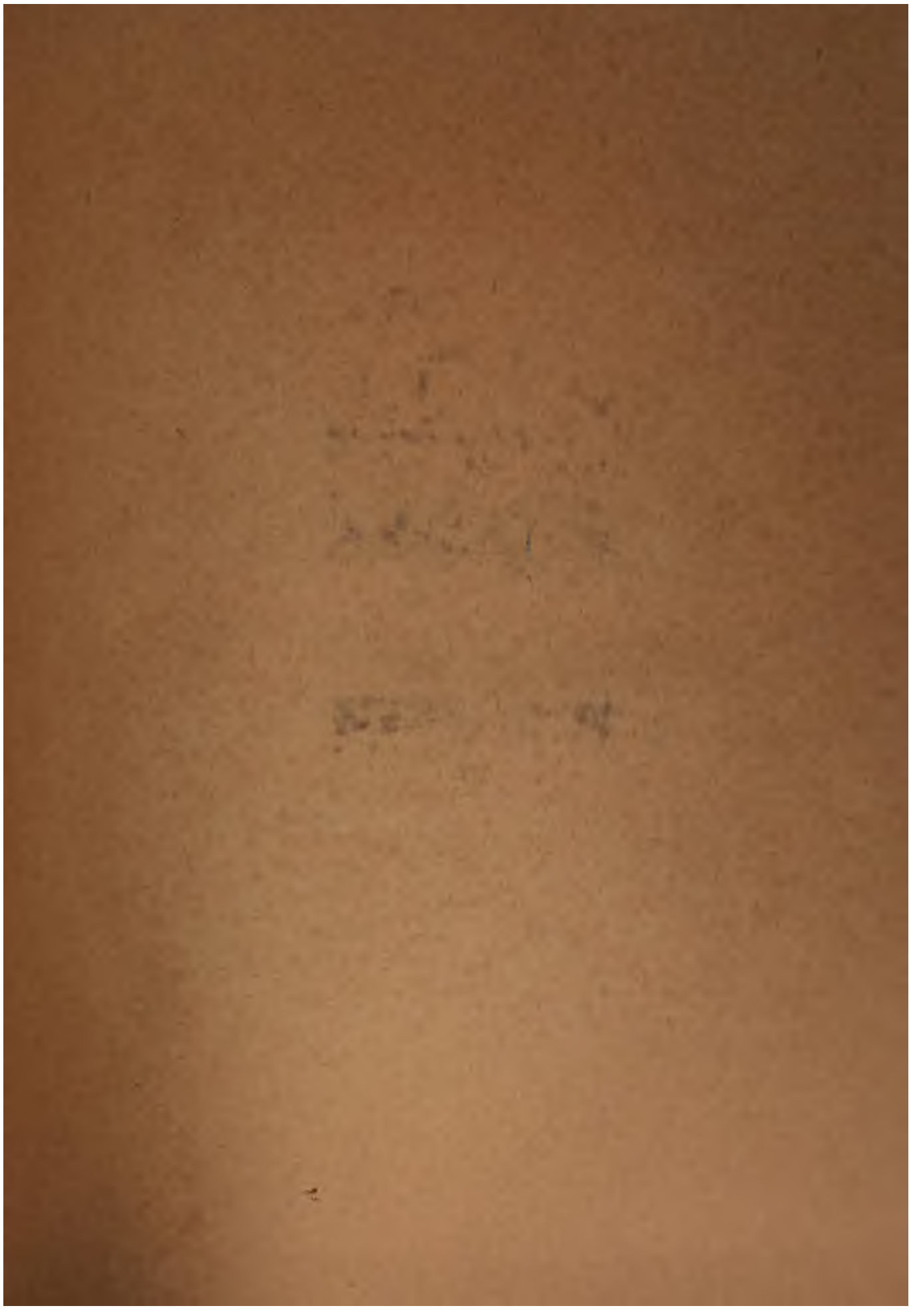

Painted by I Verkolje. *Engraved by Anker Smith A.R.A.*

ANTONY VAN LEEUWENHOEK,

Born 1632. *Fellow of the Royal Society.* Died 1723.

Wy en konnen den Heer en maker van het geheel Al, niet meer verheerlyken, als dat wy in alle zaken, hoe klein die ook in onse bloote oogen mogen zyn, als ze maar leven en wasdom hebben ontfangen, zyn al-wysheit en volmaaktheit, met de uiterste verwondering sien uit steken.

ANTONI van LEEUWENHOEK *Brieven* 9e druk 1696

THE

SELECT WORKS

OF

ANTONY VAN LEEUWENHOEK,

CONTAINING HIS

MICROSCOPICAL DISCOVERIES

IN MANY OF THE WORKS OF NATURE.

TRANSLATED FROM THE DUTCH AND LATIN EDITIONS PUBLISHED BY THE AUTHOR,

By SAMUEL HOOLE.

VOLUME THE FIRST—PART THE FIRST.

Wanneerje ſchoone dingen ſiet,
Vergaept u aen het ſchepſel niet;
Oock wilt daer op niet blyven ſtaen,
Maer laet uw' ſinnen verder gaen?
Ey klimt! o lieve, klimt om hoog,
En metten geeſt, en mettet oog,
En ſiet, dat gy tot hem genaeckt;
Die al wat ſchoon is heeft gemaeckt.

Jac. Cats werken, tweede deel pag. 400, *'tDruk*, 1726.

Inde hominum pecudumque genus, vitæque volantum
Et quæ marmoreo fert monſtra ſub æquore pontus.

Virg. Æn. vi. 728, 729.

"Lo, theſe are parts of his ways: but how
little a portion is heard of him?

Job. xxvi. 14.

LONDON:

PRINTED FOR THE TRANSLATOR,

By G. SIDNEY, BLACK-HORSE COURT, FLEET-STREET;

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THE following tranſlation was begun from the Latin Edition publiſhed in Holland, but after the tranſlator had proceeded in the work as far as the concluſion of the ſubjects deſcribed in the two firſt plates, he obtained from Holland the original Dutch Edition. He has carefully compared the two verſions, and finds that the Dutch is faithfully rendered in the Latin, and conſequently that the ſenſe of the author is not injured by the Engliſh being ſo far taken from thence. The learned reader may himſelf form a judgment of this, by the following paragraphs, taken from the Dutch and Latin Editions, whereto an Engliſh tranſlation is ſubjoined, and in which care has been taken to follow the Dutch original as literally as poſſible.

" Wy willen dan hoopen, dat de onderſoekers der natuurlyke " zaken, die tot nog toe verborgentheden dieper en dieper ſullen " op delven, om alſoo meer en meer de waarheid voor de oogen " geſtelt hebbende, van veele oude dwalingen, een afkeer te doen " krygen, waar na alle die de waarheid lief hebben behooren te " tragten. Want *wy en konnen den Heer en Maaker van het geheel* " *Al, niet meer verheerlyken, als dat wy in alle zaken, hoe klein die ook* " *in onſe bloote oogen mogen zyn, als ze maar levenen wasdom hebben* " *ontfangen, zyn Al-wyſheit en Volmaaktheit, met de uiterſte verwon-dering ſien uit ſteken.*"

Leeuwenhoeks Brieven, 99ſte miſſive.

" Speramus ergo naturæ indagatores omnem in poſterum in id " impenſuros operam, ut ea, quæ adhuc in ejus ſinu occulta latent " ulterius in propatulo ponant, atque ita in hominibus, veritatis " lumine illuſtratis, antiquorum errorum ingenerent faſtidium; " quod omnium veritatem amantium ſtudium eſſe decet. *Non enim* " *hujus univerſi Dominum atque Opificem melius nos glorificare poſſe*

" *cenſeo, quam ſi ſummam ejus Perfectionem atque Sapientiam, in om-*
" *nibus rebus, quantumvis nudo oculo exiguis, modo vitam ac incre-*
" *mentum nactis, elucentes, admiremur ſemper atque celebremus.*"

Continuatio Leeuwenhoekii Epiſtolarum. Ep. 99.

We will hope then, that the enquirers into Nature's works, by diving deeper and deeper into her hidden myſteries, will more and more place the diſcoveries of thoſe truths before the eyes of all, ſo as to produce an averſion to the errors of former times, which all thoſe who love the truth ought diligently to aim at. For *we cannot in any better manner glorify the Lord and Creator of the Univerſe, than that, in all things, how ſmall ſoever they appear to our naked eyes, which yet have received the gift of life and power of increaſe, we contemplate the diſplay of his Omniſcience and Perfections with the utmoſt admiration.*

N. B. The Dutch words printed in Italics, are written under the author's portrait prefixed to this Work.

The Dutch motto in the title page, is taken from the works of Jacob Cats, who has been ſtiled by way of eminence, the Horace of Holland; the learned reader will find it under the head of "Gedachten; Op 'tgeſichte van ſchoone Schepſels." As the Tranſlator is not poſſeſſed of any poetical talents, his readers muſt be content with plain Engliſh proſe.

" When thou beholdeſt the curious works of nature, do not be content with merely gazing at their beauties, (and canſt thou poſſibly dwell on them without looking higher?) but raiſe thy thoughts to the contemplation of Him by whom every thing that is fair and beautiful was created."

Cats's Reflections on viewing the Beauties of the Creation.

The Latin quotation from Virgil, is thus rendered by Mr. Dryden.

" Hence men and beaſts the breath of life obtain,
" And birds of air, and monſters of the main."

Dryden's Virgil, Æn. B. vi. l. 985.

THE

TRANSLATOR'S PREFACE.

CONSIDERING the high eſtimation in which the Works of Mr. Leeuwenhoek have always been held, it ſeems ſtrange, that no compleat Engliſh Tranſlation of them has ever appeared. For this, ſeveral reaſons might, perhaps, be aſſigned: what ſeems to me the moſt probable is, that there are interſperſed throughout his writings, many ſubjects of a medical and chirurgical nature, with Diſquiſitions of a peculiar kind, which to many Readers might be offenſive; ſo that I think his works have been conſidered as calculated for the profeſſional Man and Philoſopher, rather than for general Peruſal, and therefore have remained in the Dutch and Latin Tongues.

Be that as it may, when I firſt read this Author's works, I found in them ſo many wonderful and entertaining diſcoveries, with ſo much uſeful information, that I conſidered, whether it was not practicable to ſeparate thoſe parts

from what might be deemed exceptionable; and, at length, I determined to attempt the Engliſh Selection now offered to the Public. To make this more correct, I procured, from Holland, the original Edition in Dutch, by which I have been able to correct ſome few miſtakes in the Latin Tranſlation, though in general it is a very faithful one.

My endeavour has been to ſtudy perſpicuity, and uſe plainneſs of diction, ſo as to make the book intelligible to readers of every deſcription; I have given the Author's own words as nearly as a Tranſlation would admit; and I flatter myſelf that I have not omitted any thing material, which ought to have been inſerted in this Selection.

The works of Mr. Leeuwenhoek are publiſhed in Letters, written by him from time to time, to men of eminence and learned Bodies, and in particular to the Royal Society of London. The ſubjects are not placed in any regular order, and ſome of them are treated on at very different periods of time. In this Selection, I have reduced them to ſome method, by collecting under different heads, what I found diſperſed throughout thoſe Letters.

In the original Dutch Edition, the Letters are numbered progreſſively, beginning at No. 28, and the reaſon why no Epiſtles appear prior to that Number, is prefixed in theſe words:

" The preceding 27 Letters, written by the Author, " he cannot yet determine to make public in print; " therefore the 28th Letter is the firſt that is here pub- " liſhed."

If I may be allowed to form a conjecture on this occaſion, it is, that Mr. Leeuwenhoek had not, by ſubſequent obſervation, convinced himſelf of the accuracy of his firſt diſcoveries, and, on peruſing ſome of his firſt Letters to the Royal Society. I ſaw reaſon to be confirmed in that idea.

I will conclude with the following teſtimony in favour of our Author, by Sir Martin Folkes, formerly Preſident of the Royal Society.

" We have ſeen ſo many, and thoſe of his moſt ſur- " priſing diſcoveries, ſo perfectly confirmed by great num- " bers of the moſt curious and judicious Obſervers, that " there can ſurely be no reaſon to diſtruſt his accuracy in " thoſe others which have not yet been ſo frequently or " carefully examined."

Philoſophical Tranſactions, No. 380, *Sect.* v.1.

INTRODUCTION.

To thoſe who are acquainted with the works of Mr. Leeuwenhoek, or who have been much converſant in Microſcopical ſtudies, this Introduction may appear unneceſſary: but thoſe to whom the ſubject is new, will find ſo many wonders laid open to their view, as perhaps to induce a doubt of the Author's accuracy in his obſervations, or his veracity in his narrations. Indeed, the extreme minuteneſs of many of the ſubjects on which he treats, is in ſome inſtances beyond the reach of our capacities to comprehend,* although we may be fully aſſured of their exiſtence. In fact, it appears by Mr. Leeuwenhoek's writings, that the difficulty now ſtated, was

* The Spectator, in one of his papers on the Pleaſures of the Imagination, has a paſſage full to the preſent purpoſe, which is as follows:

'Nothing is more pleaſant to the fancy, than to enlarge itſelf by degrees, in its contem-
'plation of the various proportions which its ſeveral objects bear to each other, when it com-
'pares the body of man to the bulk of the whole earth, the earth to the circle it deſcribes round
'the ſun, that circle to the ſphere of the fixed ſtars, the ſphere of the fixed ſtars to the circuit
'of the whole creation, the whole creation itſelf to the infinite ſpace that is every where dif-
'fuſed about it: or when the imagination works downward, and conſiders the bulk of a human
'body, in reſpect of an animal a hundred times leſs than a mite, the particular limbs of ſuch
'an animal, the different ſprings which actuate the limbs, the ſpirits which ſet theſe ſprings a
'going, and the proportionable minuteneſs of theſe ſeveral parts, before they have arrived at
'their full growth and perfection. But if, after all this, we take the leaſt particle of theſe
'animal ſpirits, and conſider its capacity of being wrought into a world, that ſhall contain
'within thoſe narrow dimenſions a heaven and earth, ſtars and planets, and every different
'ſpecies of living creatures, in the ſame analogy and proportion they bear to each other in our

made a matter of objection by ſeveral of his cotemporaries, therefore the following paſſage in his own words, will ſerve to ſtate the objection, and the manner in which it was anſwered by the Author himſelf.

'I have often heard, that many perſons diſpute the truth of 'what I advance in my writings, ſaying that my narrations con- 'cerning animalcules, or minute living creatures, are merely of my 'own invention. And, it ſeems, ſome perſons in France have even 'ventured to aſſert, that thoſe are not in truth living creatures, 'which I deſcribe as diſcoverable to our ſight, and alledge, that after 'water has been boiled, theſe particles in it which I pronounce to be 'animalcules will be ſtill obſerved to move. The contrary of this, 'however, I have demonſtrated to many eminent men, and I will be 'bold to ſay, that thoſe gentlemen who hold this language, have

'own univerſe; ſuch a ſpeculation, by reaſon of its nicety, appears ridiculous to thoſe who 'have not turned their thoughts that way, though at the ſame time it is founded on no leſs 'than the evidence of a demonſtration. Nay, we may yet carry it farther, and diſcover in the 'ſmalleſt particle of this little world, a new inexhauſted fund of matter, capable of being 'ſpun out into another univerſe.

'I have dwelt the longer on this ſubject, becauſe I think it may ſhew us the proper limits, 'as well as the defectiveneſs of our imagination; how it is confined to a very ſmall quantity 'of ſpace, and immediately ſtopt in its operations, when it endeavours to take in any thing 'that is very great, or very little. Let a man try to conceive the different bulk of an animal, 'which is twenty, from another which is a hundred times leſs than a mite, or to compare in 'his thoughts, a length of a thouſand diameters of the earth, with that of a million, and he 'will quickly find that he has no different meaſures in his mind, adjuſted to ſuch extraordi- 'nary degrees of grandeur or minuteneſs. The underſtanding, indeed, opens an infinite ſpace on 'every ſide of us; but the imagination, after a few faint efforts, is immediately at a ſtand, and 'finds herſelf ſwallowed up in the immenſity of the void that ſurrounds it: our reaſon can pur- 'ſue a particle of matter through an infinite variety of diviſions; but the fancy ſoon loſes 'ſight of it, and feels in itſelf a kind of chaſm, that wants to be filled with matter of more ſen- 'ſible bulk. We can neither widen, nor contract the faculty to the dimenſions of either 'extreme. The object is too big for our capacity, when we would comprehend the circum- 'ference of a world: and dwindles into nothing, when we endeavour after the idea of an 'atom.'

'SPECTATOR, No. 420.'

'not attained to a degree of proficiency to obſerve ſuch objects truly.
'For my own part, I will not ſcruple to aſſert, that I can clearly
'place before my eye the ſmalleſt ſpecies of thoſe animalcules con-
'cerning which I now write, and can as plainly ſee them endued
'with life, as with the naked eye we behold ſmall flies, or gnats
'ſporting in the open air, though theſe animalcules are more than a
'million of degrees leſs than a large grain of ſand. For I not only
'behold their motions in all directions, but I alſo ſee them turn
'about, remain ſtill, and ſometimes expire; and the larger kinds of
'them I as plainly perceive running along, as we do mice with the
'naked eye. Nay, I ſee ſome of them open their mouths, and move
'the organs or parts within them; and I have diſcovered hairs at
'the mouths of ſome of theſe ſpecies, though they were ſome thou-
'ſand degrees leſs than a grain of ſand.

'But ſince it is pronounced to be incredible, that within the ſpace
'occupied by a grain of ſand ſo many animalcules can be contained,
'and that it is impoſſible for me to calculate truly ſuch numbers, I
'have thought on the following method of computation, to place
'this matter in a clearer light. I lay it down as a poſition or truth,
'that with the microſcope I can ſee the ſpace occupied by a grain of
'ſand* magnified to the ſize repreſented by the circle A B G C.
'Next, I ſuppoſe that I obſerve within this ſpace an animalcule
'ſwimming or running along, and appearing of the ſize repreſented
'at D. Taking the meaſure of this by my eye, I conceive the axis
'or thickneſs of the animalcule thus pictured at D, to be the twelfth
'part of the axis of the grain of ſand repreſented by ABGC; there-
'fore, by the common rules of arithmetic, the ſolid contents of a
'ſphere or globe whoſe circumference is deſcribed by the circle
'A B G C, will be 1728 times larger than a ſphere of the ſize of D.

* 'A grain of ſand the Author in another place deſcribes to be of that ſort called ſcowering,
'ſand, or glaſs-grinders ſand.

'Next, I obſerve another kind of animalcule, which, meaſuring, by 'my eye through a good microſcope, I judge the axis or thickneſs 'of it to be one fifth, but ſuppoſe it only a fourth part of the ſize of 'the firſt animalcule D, ſuch as is repreſented by the circle E, and 'then, by the ſame rule, the ſize of D muſt be 64 times larger than 'that of E; and if this laſt number be multiplied by the former, '(1728) we ſhall find that 110,592 animalcules of the ſize of E, '(ſuppoſing their bodies to be of a ſpherical figure), will be required 'to make up the ſize of the ſphere A B G C. Laſtly, I perceive a 'third kind of animalcule, the ſize of which appears to be only a 'tenth part of the animalcule at E, ſuch as the point at F denotes; 'and that conſequently, one thouſand of theſe will be more than equal 'to the ſize of that at E. And, if this number be again multiplied by 'the former, it will be plain to demonſtration, that more than an 'hundred millions of animalcules can be contained within the com-'paſs of a grain of ſand*.'

This paſſage reſpects the ſize of animalcules, which the Author repreſents by compariſon with the known ſize of a grain of ſand; other minute objects which he frequently deſcribes, are, the veſſels in the bodies of inſects, the threads of Spiders, the filaments or threads of wool, the fibres compoſing the fleſh of animals and the like. All theſe he conſiders as of a cylindrical form, that is to ſay,

* 'The ſolid contents of ſpheres being in the ſame proportion as the cubes of their axes, 'the mathematical demonſtration of the Author's poſition is ſet down by him thus:—

12	4	10	1728
12	4	10	64
144	16	100	6912
12	4	10	10368
1728	64	1000	110,592
			1000
			110,592,000

if hollow, like a round pipe, and, if ſolid, like a round ſtick, wire, or rope, and he conveys to his readers an idea of their minuteneſs, by comparing them with the known ſize of a ſingle hair. The method uſed by him in aſcertaining this proportion he deſcribes as follows:

'In examining the inteſtines of flies and other inſects by the mi-
'croſcope, I have diſcovered veſſels conveying the blood and juices,
'the ſmalleſt ramifications or branches whereof appeared to me more
'than two hundred thouſand times leſs than an hair of my beard.
'And I will here explain how I compute this proportion, which to
'many may appear wonderful.

'I have a plate of copper, with many lines engraven on it, and
'divided into a number of ſmall equal parts. I then carefully ob-
'ſerve how many of theſe parts one hair taken from my beard, and
'ſeen through the microſcope, appears to cover. Suppoſing that the
'diameter of this hair, when magnified, appears equal to fifty of
'thoſe parts, then with the point of a needle I trace on the copper
'a line, of the ſame ſize by the naked eye as is equal to one of thoſe
'ſmall veins or veſſels in a fly, ſeen through the microſcope; and I
'find that nine of thoſe ſmall lines ſo traced with a needle, when
'placed cloſe together, are a fiftieth part of the diameter of the hair.
'If then 450 diameters of thoſe ſmall veins which I moſt plainly ſee in
'a fly are no more than equal to the diameter of one hair taken from
'my beard, it follows,* by the rules of arithmetic, that one of ſuch

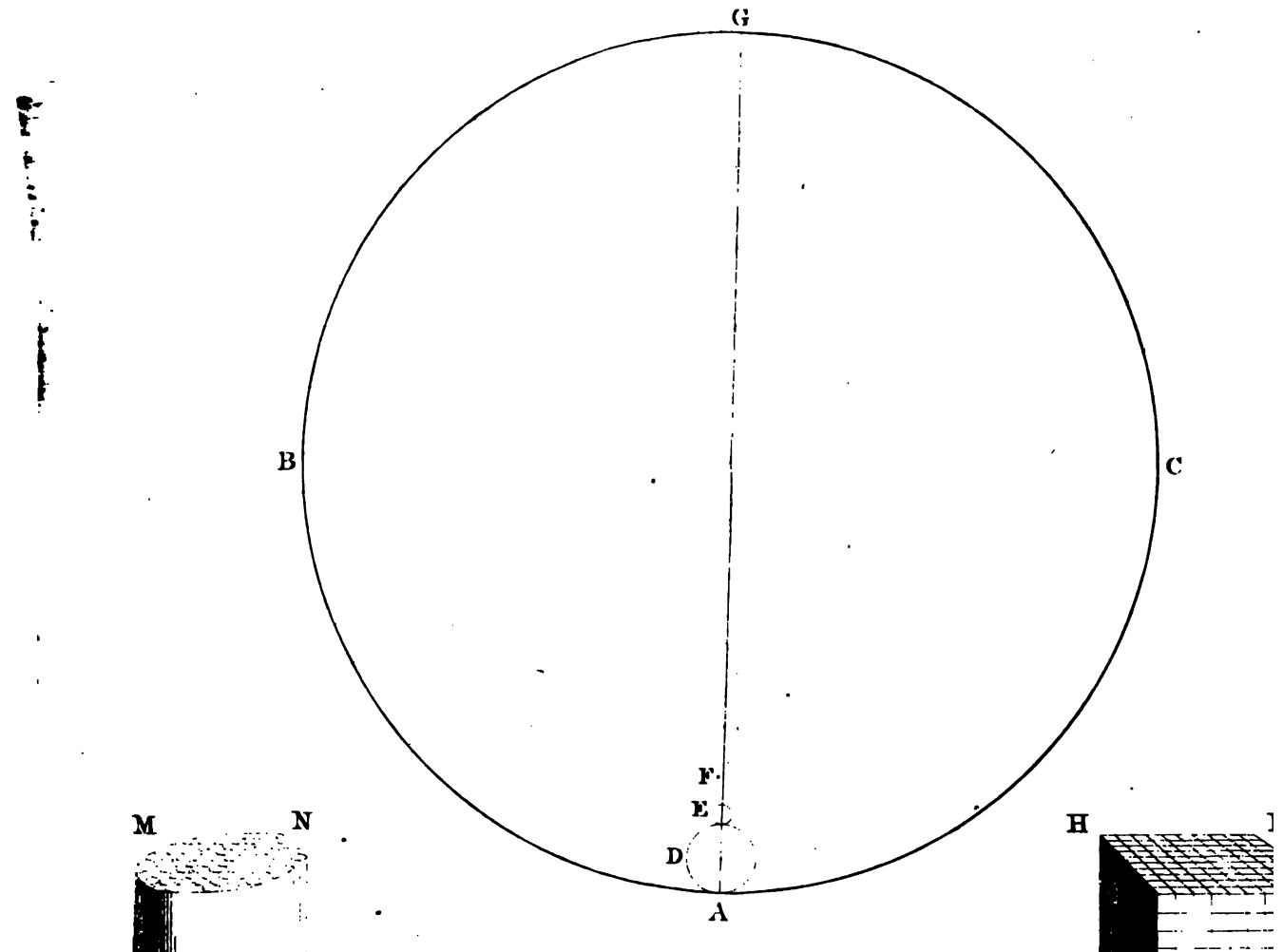
* Mr. Leeuwenhoek here conſiders the hair to be round, as well as the ſmall veſſels he alludes to, and, ſuppoſing each of theſe to be cut through or acroſs the middle, the ſection would exhibit a circle. Now the areas of circles being in proportion to the ſquares of their diameters, the Author's propoſition is mathematically demonſtrated thus:

$$\begin{array}{r} 450 \\ 450 \\ \hline 22500 \\ 1800 \\ \hline 202{,}500 \end{array}$$

'hairs is more than 200,000 times larger than thoſe very ſmall blood 'veſſels in a fly.'

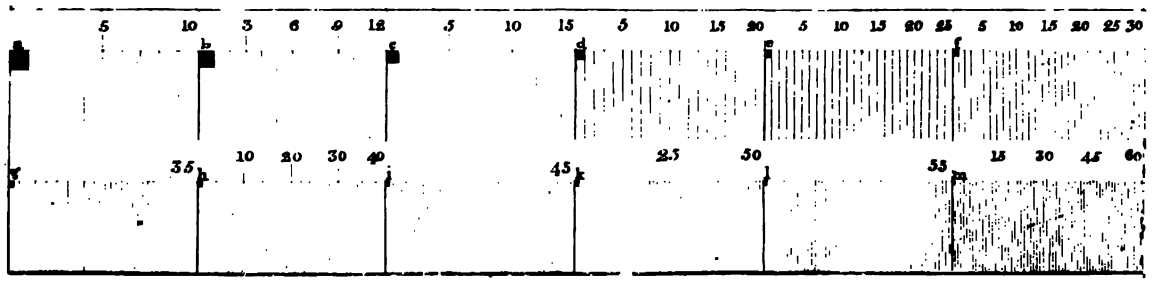
The author ſometimes computes the ſize of ſmall objects by aliquot or equal parts of an inch, and, for the more readily placing theſe before the reader's view, the tranſlator has ſubjoined a ſcale of inches divided into ſeveral different numbers of equal parts, and in each of theſe diviſions is marked the proportionate ſize of the ſame number of parts in a ſquare inch.

Further, at H I K L, is given a repreſentation of a cube, and at M N O P, a drawing of a cylinder, in order to convey an idea of thoſe figures to ſuch readers as have not been much converſant in the doctrine of ſolids. The number of parts or circles contained in the cylinder, will not be found to anſwer ſo exactly to the arithmetical computation as thoſe in the cube, and this is occaſioned by the interſtices or ſpaces between the circles in the cylinder, which only touch each other in a point,



The Aliquot parts of a Square Inch are marked at the letters a.b.c.d &c.

a *denotes the*	100 p^{ts}	g	1225
b	144	h	1600
c	225	i	2025
d	400	k	2500
e	625	l	3025
f	900	m	3600



A Scale of Inches divided into different numbers of aliquot or equal parts.

OF THE OAK.

The Nature of its Production; the different Degrees of Goodneſs in Oak Timber; and the Cauſes of that Difference. The Author's Opinion as to the proper Seaſon for felling Timber.

IN order to form a true judgment of the nature of this Tree, and the better to comprehend the following deſcriptions of the * veſſels, which compoſe the ſame, let us firſt attend to Plate I. *fig.* 1 †, B C D, and imagine it to repreſent the ſurface of an Oak when cut tranſverſely or acroſs the middle, on which ſurface eighteen circles appear; which circles are the clear and undoubted marks of eighteen years growth, the tree being increaſed every year by the addition of one circle, (and in the latter of thoſe years the circles are the largeſt, though not all of equal magnitude, but in proportion to the fertility of each year.) The ſmall portion of this wood, deſcribed in the next figure is marked in the ſixteenth circle by the letter E. Farther, ſuppoſing the tree to be ſawn acroſs, as above-mentioned, and afterwards planed or poliſhed, we ſhall obſerve throughout the ſurface, ſtreaks or creaſes, reaching from the centre A, to the circumference B, and theſe are veſſels conveying the nu-

* By the word veſſels, are to be underſtood, throughout this Work, ſmall tubes, or pipes, running in different directions, in the ſubjects treated of.

† This figure, which in the original, is only ſo many circles, the Tranſlator has cauſed to be engraved from a piece of Oak of the ſize here deſcribed; at F is repreſented a knot which was in the tree.

tritive juices of the plant outwards towards the bark, as in the next figure will be more fully explained.

Fig. 2, A B C D, repreſents a ſmall piece of Oak, drawn as nearly as could be done, according to its appearance ſeen through a microſcope, prepared by me for that purpoſe, and which piece of wood appears to the naked eye of the ſize repreſented at *fig.* 2, X.

The dark ſhades at F F, F F, indicates the part where, towards Autumn, the vegetation and increaſe for that year ceaſe; and about this time, and in this part, the wood becomes exceeding hard, being compoſed of ſuch ſmall veſſels, that it is difficult, and at laſt impoſſible to diſtinguiſh them, for which reaſon they aſſume the appearance of dark ſtreaks or ſhades. Between the letters F F, F F, is contained that ſpace, or thickneſs, which the tree acquires through its circumference, in the ſpace of one year.

This ſpecies of timber tree, has five different kinds of veſſels, three riſing perpendicularly, and two extending, or ſpreading horizontally.

E E E, repreſent the firſt ſort of theſe perpendicular veſſels, which are very large, and are produced in the ſpring, with the firſt riſe of the ſap. The inſides of theſe veſſels are full of a kind of veſicles, or little bladders, compoſed of very thin membranes, or ſkins, and theſe are to be ſeen in *fig.* 3, where, at the letters L K I M, is repreſented a ſection of one of theſe large veſſels, divided longitudinally, and ſeen through the microſcope.

The ſecond ſort of theſe perpendicular veſſels is much ſmaller, and is alſo compoſed of exceeding fine membranes, intermixed with a kind of ſpots, which by the microſcope, appeared to my eye like globules, or little balls, as repreſented in *fig.* 4, O N, which exhibits one of theſe ſecond ſized veſſels, divided longitudinally.

The third kind of theſe perpendicular veſſels is exceeding ſmall, but in great numbers: likewiſe compoſed of exceſſively minute

membranes, and theſe are alſo repreſented when cut longitudinally, or lengthways, at *fig.* 4, P Q.

All theſe perpendicular veſſels, which are found in ſo ſmall a piece of wood as that before repreſented, and which in ſize, is about the ninetieth part of a ſquare inch, do amount in number, in my opinion, to twenty thouſand; ſo that an Oak tree of four feet in circumference * contains, according to my computation, more than three thouſand two hundred millions of theſe perpendicular veſſels, and in a tree of no more than one foot in circumference, will be found two hundred millions of ſuch veſſels.

Theſe perpendicular veſſels do, for the moſt part, infuſe, or inſtil their juices into other veſſels, which are almoſt innumerable, lying in an horizontal poſition in the tree, and by the means of which it's bulk or thickneſs is daily increaſed: theſe veſſels are of two ſorts.

Fig. 2, G G G, repreſents one ſort of theſe horizontal veſſels, which originally, or at the firſt formation of the plant, are derived from the marrow, or pith, in the centre of it; but afterwards, in great numbers, take their origin from the perpendicular veſſels. Theſe veſſels appeared to my eye like dark ſtreaks; but in order to examine them more clearly, I cut a piece of the wood lengthwiſe, ſo that they were cut exactly acroſs, and then each of them appeared to be formed of five, ſix, or even ſeven veſſels joined one on another, as they are repreſented in *fig.* 4, intermixed among the perpendicular veſſels.

The other ſort of horizontal veſſels, lying in great numbers or cluſters, cloſely joined to each other, though not evenly diffuſed throughout the wood, when examined in their horizontal poſition, appear as in *fig.* 2, A B, or C D, (but when cut tranſverſely,

* The circumference of a circle being about three times it's diameter, a tree of four feet in circumference, will be ſixteen inches in diameter, and one of a foot in circumference, four inches diameter, the ſize repreſented in *fig.* 1.

they are repreſented as ſeen by the naked eye, in *fig.* 5, R S,) and where they are repreſented magnified and ſeen longitudinally in *fig.* 2, I have in many places drawn croſs lines, to repreſent what I conceive to be minute valves, and though I could not ſee them ſo diſtinctly, as here they are drawn, yet I cannot doubt of their exiſtence, having frequently ſeen theſe valves in other woods, and particularly, very diſtinctly in the Elm; beſides, it ſeems evident to me, that without ſuch valves the tree could not be increaſed in its bulk, on account of the great force required to ſeparate and looſen the bark from the tree, in the time of ſpring, and alſo for the violent burſting open of the bark, to allow for the growth and increaſe of the wood: and if there were not ſuch valves, the juices, which by the action of the ſun are drawn outwards, would, at ſun ſet, when that motion of the juices ceaſes, be drawn back again, and their exertions to diſtend the bark become fruitleſs. A portion of theſe veſſels is repreſented in *fig.* 4, TV, which figure is drawn from a microſcope of greater magnifying power than that from which the perpendicular veſſels are drawn, in order that theſe horizontal ones may be more clearly ſeen: and in this ſmall piece of wood, and in this little ſpace, which is no more than the ſeven hundredth part of a ſquare inch, are more than two thouſand veſſels.

It is well known that there is a great difference in Oak Timber, namely, whether it grew in mountainous ſituations, or low lands, and whether in warmer or colder climates, and laſtly, whether it was of quicker or ſlower growth. As to the ſpecimen of Oak which has been juſt deſcribed, it was taken from a tree of the beſt quality, very compact and cloſe grained, and which had been very flouriſhing in its growth.

Oak timber of this ſuperior quality we muſt not expect to find in the Northern or cold countries, but in the warmer ones. The very beſt timber that we have here, in Holland, is brought down the

Rhine from the places of its growth, which are nearly in the ſame parallel of Northern latitude with ourſelves. The Oak which we have from Riga, Koningſberg, and Dantzick, is very periſhable, and of a ſpongy nature, becauſe it grows in a colder climate, and increaſes in it's bulk much more ſlowly than that before-mentioned; but yet this wood, though ſo periſhable, is deemed the beſt for making beer-barrels, becauſe it does not impart any ill taſte to the beer, the reaſon of which I take to be, that in cold climates the Oak does not acquire ſo much acrid ſalt as it does in warmer ones; but I do believe, that if the better ſpecies of Oak, after being cleft into ſtaves, were to be ſoaked in water for a certain time, this acrid ſalt would be extracted from it, and that the caſks made of it would be greatly ſuperior to thoſe made of Riga Timber.

The Oak, as has been before obſerved, in the beginning of its growth every ſpring, produces very large veſſels, but the reſt of the year much ſmaller ones; conſequently, when the tree ſo flouriſhes as to acquire an increaſe in it's ſemi-diameter, or on one ſide of it's outward ſurface, of one half, one third, or a quarter of an inch, there will be in this ſpace only one ſeries, or row of ſuch large veſſels; but on the contrary, where the increaſe is ſlow, then, within the ſame ſpace of one half, one third, or a quarter of an inch, there will be formed from twenty to ten, or eleven ſuch rows of large veſſels. This great number of large veſſels in ſo ſmall a ſpace, not only renders the wood very porous and brittle, but alſo very periſhable, eſpecially if it is uſed in works expoſed to much moiſture, and where there is no free current of air: and hence it is, that ſhips built of French or Engliſh Oak, are much more durable than thoſe built of timber growing in the more Northern and cold countries.

In order, more clearly, to explain the nature of the beſt Oak timber, let us revert to *fig.* 2, repreſenting a portion of a tree which, in one year, had acquired in thickneſs almoſt a ſixth part of an inch

in it's ſemi-diameter, or one third of an inch in the whole, and in this, one row or circle, and no more, of the very large veſſels, before deſcribed, had been formed. Then, to diſcern the difference between this timber and that brought from Riga and Koningſberg, let us attend to *fig.* 6, ABCDEF, wherein is exhibited a ſmall piece of ſuch timber cut tranſverſely, and drawn from the microſcope.

The piece of wood which, in this figure, is repreſented by ABC, or DEF, contains about the fifteenth part of an inch in length*, and this length, or rather this thickneſs, the tree had acquired in two years growth, ſo that AB denotes the thickneſs produced in the tree in one year, and is about the thirtieth part of an inch in length; BC or ED, indicate the increaſe of the following year; ABC and FED repreſent the larger horizontal veſſels, which in *fig.* 2, are explainedby AB or CD; and the dark lines HHHH, indicate the ſmaller horizontal ones, which in *fg.* 2, are deſcribed by GGG: all the round cavities, of which there are three different ſizes repreſented in this figure, and which are found within the compaſs of the thirtieth part of an inch in length, are the three different ſorts of perpendicular veſſels before deſcribed, Hence we ſee that in a tree, which is augmented in ſize, in it's ſemi-diameter, one inch, or in the whole diameter two inches and no more, in the growth of thirty years, there will be formed thirty rows, or ſeries of large veſſels; from whence it follows, that the greateſt part of Oak Timber, of ſuch ſlow growth, muſt be very ſoft and periſhable: and if on the other hand we conſider, that Oaks growing in a warmer climate may, in one year, increaſe in ſize, in their ſemi-diameter half an inch, or an inch in their whole diameter, we may eaſily perceive how large a portion of wood will be formed in them, having only one row of the large veſſels in it, and how firm, ſolid, and durable ſuch wood muſt be.

* This ſize is repreſented in *fig.* 6, at X.

Let a tree of flouriſhing growth be increaſed in magnitude, in the ſpace of a year, one fourth part of an inch, in ſuch a ſpace will be produced one circle of the large veſſels; another tree growing in a colder climate ſhall require eight or ten years growth to increaſe in the ſame degree: in this laſt tree, within the fourth of an inch ſpace will be formed eight or ten circles of large veſſels, the neceſſary concluſion is, that Oak Timber growing in cold climates muſt be ſoft and periſhable, and it muſt be acknowledged that Oak timber growing in this country of Holland, is ſuperior in quality to that produced in more Northern latitudes: again, that the Oak Timber of Brabant and Flanders, is ſuperior to ours, and laſtly, that the French and Engliſh Oaks are the moſt excellent of all.

One thing muſt however be conſidered, which is, that the very largeſt Oaks are not always ſo valuable as trees of a more moderate ſize, that is to ſay, if they were of good growth, and are free from decay; for though large trees, in the firſt thirty, forty, or fifty years may grow very faſt, and produce excellent timber, yet when they come to the age of an hundred, or an hundred and twenty years, the circles of wood added every year, become very narrow, and the thickneſs increaſes ſlowly, ſo that the large veſſels in the wood approach near together, and conſequently the exterior or outward parts of ſuch large timber become very ſoft, in compariſon with the inner part of it.

It is the general opinion in this Country that timber is much more ſolid or durable when felled in winter than in ſummer. But I think that if we examine this opinion, we ſhall find it to be erroneous.

It is true, that if timber be felled in the ſummer time, the bark can much more eaſily be ſeparated from it than in the winter; for the wood newly formed each year always adheres to the bark, and the bark is every year propelled or driven outwards from the laſt

year's wood, and as the tubes or veſſels of which ſuch newly formed wood is compoſed, are during the time of their growth not ſolid, but of a very ſoft texture, this is the reaſon why the bark can be ſo eaſily ſtripped off in the ſummer time. But that any part of the tree, except that of the new growth, ſhould be more ſolid in winter than in ſummer, ſeems to be altogether impoſſible; for it is plain to demonſtration that all trees are compoſed of multitudes of ſmall tubes or veſſels, which are formed every year by the tree's growth, and that when once formed they preſerve their ſhape and ſize, without any alteration, although the tree be above an hundred years old. Theſe tubes, which in all ſeaſons are filled with juices, are neither leſs in winter nor larger in ſummer, for the juice which circulates through them is at all times the ſame. But if it were poſſible that the ſubſtance of trees in winter could be more cloſe or compact, and in ſummer more ſpongy or diſtended, it would follow that the hard and dead bark ſurrounding the tree would in winter be ſeparated from the wood, and in ſummer more ſplit open than it is found to be; but ſince we do not obſerve this to happen in either inſtance, it muſt be the better opinion, that timber felled in ſummer is equally good with that cut down in winter; and if any one will take the trouble to examine thoſe ſmall chinks or fiſſures which are produced in the bark during the tree's growth in ſummer, he will find that trees are not increaſed in their ſize or ſubſtance in an haſty manner, but by very ſlow degrees.

OF THE FIR.

The different Degrees of Goodneſs in Fir Timber, how diſcoverable; the minute Veſſels which enter into the Compoſition of this Tree deſcribed at large.

IN treating of the Oak I have conſidered, that the ſpecies of it growing in warm climates, is ſuperior to that which is produced in cold countries. But we muſt not imagine this to be the caſe with all Woods; on the contrary the Fir Timber growing in cold countries is ſuperior to that produced in warm ones, where its growth is rapid. For the perpendicular veſſels of which the Fir is compoſed are comparatively ſmall, and though we may ſee here and there in this wood a large perpendicular veſſel, that is no great exception to the general nature of it.

In the Fir, at the beginning of its growth every year, the perpendicular veſſels, (which are all of the ſame kind), are formed twice as large as thoſe towards the end of the ſeaſon, when the growth ceaſes, and theſe latter-formed veſſels are, in reſpect of their component woody parts, very compact and cloſe, having very ſmall cavities, and conſequently producing durable timber; and the leſs this tree grows every year, the greater number of theſe compact veſſels enter into its compoſition. Hence we may gather, that if, upon examining Fir Timber at the ends, when it has been

cut or ſawn acroſs, we obſerve the circles, denoting each year's growth to approach very near together, we may eaſily conclude that ſuch timber is firm and durable, eſpecially if we perceive great part of theſe circles to be moiſtened or tinged with a reſinous or gummy ſubſtance, named Turpentine.

The production or growth of the Fir is ſhewn in Plate I. *fig.* 7. which repreſents a ſmall piece of this wood, as ſeen by the microſcope, when cut tranſverſely, in order to ſhew the difference between the perpendicular veſſels formed in the Spring, and thoſe produced in Autumn, when the growth ceaſes.

The natural ſize of the ſpace contained between A B C, or E F G, is about the fifteenth part of an inch in length; A B F G, denote that portion of the wood formed towards the latter end of the year, and the line of ſeparation appearing at B F, is the place where the increaſe for that year ceaſed. B C E F indicate a part of the ſame wood, produced in the beginning of the following year.

D D, and G G, are the horizontal veſſels, which in this wood are placed very cloſe to each other, ſo that when cut tranſverſely it is difficult to diſtinguiſh them.

In this figure, we ſee the difference between the veſſels formed at the beginning and at the end of each year's growth. And if the wood here repreſented, within the ſpace A B C (which is the fifteenth part of an inch) required two years to enlarge the ſemidiameter of the tree to that thickneſs, it follows, that in this ſpace there will be two rows or circles of the compact veſſels pictured, between A B. Moreover, the piece of wood which is here deſcribed was from a tree of quick growth, and timber of ſlower growth not only would produce fewer of the large veſſels, but alſo thoſe veſſels firſt formed in the ſpring would be ſmaller in proportion, eſpecially if growing in a colder country, and in a good ſoil. In a word, the nearer the circles before mentioned approach together, the ſlower was the growth, and this ſpecies of Fir is the moſt durable.

In reflecting upon the nature of the tubes or veſſels of which wood conſiſts, I conſidered with myſelf, whether each of theſe tubes was not formed of two diſtinct kinds of exceſſively ſmall veſſels or coats, one ſort extending lengthways, and the other ſort encompaſſing each tube in a circular direction, as I had obſerved the quills * of feathers to be formed, in order to give to each tube a degree of ſtrength and firmneſs.

To inveſtigate this, I examined ſeveral kinds of wood, and particularly the Fir, and at length I obſerved in ſplitting the larger tubes or veſſels of the wood, that ſome of them were indented or jagged in the ſplitting, and I alſo imagined that I ſaw the tube to conſiſt of ſmaller veſſels in a ſtrait perpendicular direction which were not diffuſed all over the membrane or coat, but only placed on each ſide of it, whence I gathered, that though the minute veſſels, ſome of which I conceived to extend longitudinally, and others to encompaſs each tube of the wood, cannot always by reaſon of their exceeding ſmallneſs be diſcovered, yet that the tubes are in reality formed like the quills of birds in order to give them the greater ſtrength.

In further proſecuting this inquiry, I procured a piece of the Pitch Pine or Fir newly felled, and which had been of very quick growth; and having placed a ſmall part of it before the microſcope, I directed the Engraver to copy the figure of it as exactly as poſſible.

Fig. 8, ABCDEFG, repreſents this ſmall piece of wood, which I ſplit longitudinally as thin as poſſible. It's extreme thinneſs brought clearly into view a great number of globules contained in the veſſels of this wood, and which afford a moſt pleaſing ſpectacle, not only on account of their exact globular figure, but alſo becauſe in each of the globules is a lucid or bright ſpot.

This ſmall piece of wood I found particularly eligible for my

* The Author's examination of this ſubject will appear in the courſe of the work.

obſerved, which laſt diſcovered veſſels were exceeding ſmall in compariſon of the former; ſo ſmall, indeed, that if a large grain of ſand were divided into ten millions of parts, theſe veſſels would ſtill be impervious to them. Hereupon I concluded that all the perpendicular veſſels which I had before diſcovered in this wood, and through which I had ſuppoſed the juices for the nouriſhmet of the tree, and its fruit, were conveyed, were really only air veſſels; for thoſe which I now name air veſſels are ſurrounded with three or four of the very ſmall veſſels before mentioned. And I am clearly of opinion, that theſe minute veſſels do conſtitute and form thoſe others which I name air veſſels, and connect them one with another; and that theſe ſmaller veſſels convey all the nutritive ſubſtance for the ſupport of the tree, its leaves and fruit, and that therefore they may properly be named arterial veſſels.

The wood which in *fig.* 8, is repreſented ſplit longitudinally, I now cut or divided tranſverſely, to ſhew the nature of theſe veſſels when inſpected into or looked down upon, if I may ſo expreſs myſelf; and at *fig.* 11, U V W Y Z, a portion of it is repreſented as ſeen by the microſcope, the natural ſize of which was no more than could be covered by a middling ſized grain of ſand; and in this figure, between the veſſels compoſing the wood, or the air veſſels before mentioned, are ſeen the very minute veſſels which I call the arteries of the wood cut tranſverſely; but as they are ſo very minute, I cauſed four of the air veſſels to be drawn ſeparate as viewed by a ſtill deeper magnifier, that theſe laſt might be the better diſtinguiſhed, and theſe are ſhewn at *fig.* 12, as they lie between the air veſſels.

The dark ſtreaks which are repreſented in *fg.* 11, at W Y Z, are a ſmall part of the horizontal veſſels divided longitudinally, and which veſſels are repreſented in *fig.* 8, between G H, and I K.

To this deſcription I muſt add a little piece of the ſame wood which

I cut longitudinally, but in a different manner from that deſcribed in *fig.* 8; for as in that figure the wood is repreſented when ſo ſplit that the air veſſels, and thoſe ſmaller ones which I call arteries, and alſo the horizontal tubes of the wood, are all divided longitudinally, here on the contrary the perpendicular veſſels are ſplit or divided longitudinally, but the horizontal ones are cut obliquely.

Fig. 13, L M N O, repreſents ſuch a particle of the wood in which the horizontal veſſels may be ſeen placed ſo cloſe to each other as to be only ſeparated by one or other of the air veſſels. Theſe horizontal veſſels lying ſo cloſely and regularly beſide each other it is no wonder that this kind of wood is of all, the moſt eaſily ſplit, and ſtrait in the ſplitting.

I have cauſed a ſeparate drawing to be made of theſe horizontal tubes or veſſels in their poſitions adjoining to each other, in order the better to diſtinguiſh how they lie among the perpendicular ones.

Fig. 14, P Q, repreſents theſe horizontal tubes or veſſels, many of which are ſeen in *fig.* 13. Theſe veſſels in ſome places lie twice as cloſe together as they do in others; and upon examining them with the greateſt accuracy I was able, I muſt ſay that I ſaw two kinds of theſe horizontal veſſels or tubes of the wood, one ſort of which was ſo much ſmaller than the other as almoſt to eſcape the ſight.

For the more fully elucidating this ſubject, and for the information of any who may have the curioſity to repeat my obſervations, I have in *fig.* 15, given a drawing of the manner in which I cut or ſplit the wood. In this figure A B C D F, repreſents the fourth part of a round piece of the tree or a branch of it, of which B denotes the center of the tree or branch; at G is ſhewn how the particle of wood, repreſented in *fg.* 8, was ſplit off; at C, how the particle repreſented in figures 11 and 12, was cut off, and at E, how the particle repreſented in *fig.* 13, was ſplit off.

I have ſometimes (as I before hinted) ſeen ſome of the perpendicular or aſcending veſſels in the fir, much larger in diameter than others; but theſe are ſo few, that it is very rare to obſerve them.

In *fig.* 8, between B and C, are to be ſeen the minute round apertures in thoſe parts of the aſcending tubes or air veſſels, where the horizontal ones are ſeen, which apertures I conceive are deſtined to tranſmit air or the juices of the tree, from the aſcending to the horizontal veſſels.

Theſe diſcoveries of mine, reſpecting the ſmallneſs or thinneſs of the veſſels or tubes, compoſing the ſubſtance of trees, may not eaſily be credited by many, as not comprehending how, by reaſon of their exceeding ſmallneſs, any juice or liquor can poſſibly paſs through them, and, what is more difficult to conceive, how through ſuch veſſels aſcending perpendicularly, any nutritive ſubſtance can be derived from the root of the tree to the extremities of the upper branches.

But as, on the one hand, it is out of the reach of our finite capacities to comprehend the extent of the Univerſe;* ſo on the other, we are equally unable to conceive the minuteneſs of the veſſels and component parts of which not only animals, but alſo vegetables are formed, and much leſs, how the parts of matter are united together, or how one part grows out of, or is added to, another.

* This ſentiment is more fully expreſſed and largely dilated on, in the Spectator, No. 420, and many of the reaſonings in that Paper ſeem to have been taken from the diſcoveries then newly made by our Author and his cotemporaries.

OF THE WEEVIL OR CORN-BEETLE.

Wherein the common opinion that this Inſect is bred in Corn ſpontaneouſly, is ſhewn to be erroneous; the true nature of its Generation explained; with the means to preſerve Corn from its infection.

I HAVE heard it ſtrongly argued, that the Weevil or Corn-beetle, (which is a very noxious inſect, well known to corn dealers and bakers in this country,) is produced by what is called equivocal or ſpontaneous generation, that is to ſay, from inanimate ſubſtances without any parent. The principal reaſons alledged in ſupport of this opinion are, that we often find this inſect in a new granary, where never wheat was kept before, and therefore it is deemed a neceſſary concluſion, that Weevils are not propagated by the ordinary courſe of generation. Again it is ſaid, that we may open many grains of wheat, which are ſound and uninjured, ſo that no mark of a perforation or hole, ſhall be diſcernible on the outſide, yet within theſe grains ſhall be found perfectly formed and living Weevils.

The anſwer which I have given to theſe arguments has been, that theſe little animals may, by ourſelves, be removed from one granary to another without our knowledge: for ſuppoſing the perſon employed to remove corn, to have come out of a granary, or barn, infeſted with Weevils, he may eaſily carry ſome grains of corn containing them, or ſome of the inſects themſelves, ſticking about his clothes, or in his ſhoes, and thus remove them into a granary where none

had ever been. Beſides, the ſhip, waggon, or cart, employed to carry corn, may be infected with Weevils, by having carried grain in which they abound, and thus from a few of theſe inſects, multitudes may be produced by the ordinary courſe of generation.

But in order fully to inveſtigate the truth of this, I deſired the perſons who had argued this matter with me, to bring me the firſt Weevils they themſelves ſhould find, (it being then the winter ſeaſon); and on the 13th of March, I received ſome grains of wheat, (many of which had the inſides eaten away) mixed with Weevils.

I took three glaſſes, in each of which I put ſix, eight, or nine Weevils, and eight, ten, or twelve grains of wheat, which wheat I was the more aſſured could not be infected, becauſe it had been kept for ſeveral months, cloſely covered up, in my ſtudy. In a fourth glaſs I put ſome Weevils without any wheat, but this laſt mode of experiment I afterwards rejected, obſerving that in the ſpace of twelve days they all died. As to the other three glaſſes, the weather being cold, and, obſerving the animals, for the moſt part, to lie motionleſs, I put them into a leather caſe, which I always carried about me. And I had no doubt, but I ſhould clearly prove to all, that the Weevil proceeds from a maggot, for which reaſon I frequently examined theſe objects by the microſcope.

I, at firſt, entertained an opinion, that the Weevil, like the Silkworm's moth, and many other inſects, did not, while in that ſhape, take any food: but herein I found myſelf miſtaken, and obſerved that the Weevil not only feeds upon wheat, but that it can excavate or ſcoop out the whole contents of every grain, and creep about in the inſide, being provided with a beak, or trunk of a great length, in proportion to the ſize of its body, at the extremity of which are certain exceedingly ſmall organs, or inſtruments like teeth, and with theſe it can bore or pierce through the outward huſk or ſhell of the wheat, and thus open to itſelf a paſſage to devour the contents.

At a fortnight's end, namely, on the 27th of March, I obſerved

ſome of theſe Weevils coupled together, and from this time I frequently inſpected them, but ſaw no appearance of any living creature being produced from them until the 10th of June, when I obſerved lying among the Weevils and the wheat, two ſhort and thick little maggots, one of them about the ſize of a large grain of ſand, and the other about one fourth part larger: ſeeing this, I opened one of the glaſſes in which I had encloſed ſix Weevils, and examined the different grains of wheat that had been put in with them, and found two of them to be entirely hollow and empty; from another of the grains, which by the external appearance was the leaſt eaten or conſumed, but had many ſmall perforations or little holes not diſcernible by the naked eye, I drew out a perfectly formed Weevil, which was of a yellow colour: whereas thoſe which were at firſt brought to me, and had been ſhut up in the glaſs for three months, were of a deep red, almoſt approaching to black.

In another grain of the wheat I found a Weevil, of a very pale or white colour, with its claws, horns, and beak, or trunk, lying cloſe to its body, in exact order, as we ſee the wings and legs of a Silk-worm's chryſalis or aurelia, when it is almoſt arrived at the ſtate of a flying inſect, only with this difference, that the unformed Weevil is not incloſed in a ſhell or caſe, like the aurelia of a ſilk worm.

In other grains of the wheat I found maggots of different ſizes, and from one grain I took out a perfectly formed Weevil, whoſe white colour was changing to a red, and which was continually in motion.

Examining the other glaſſes, I found ſome of the grains of wheat perforated with little holes, and others half eaten. Some of the Weevils which had been ſhut up in theſe glaſſes I opened, and in one of the females, I found five white eggs, which I conceived to be of their full ſize: in others I obſerved eggs, ſome of which were arrived to maturity, and others gradually leſs and leſs.

Hence I concluded, that whereas the Silk-worm's moth, living

only a few days, in that time lays a multitude of eggs and then dies: on the contrary, the Weevil, which every day produces but few eggs, is a long lived animal, and by this means may be as prolific as Silk-worms or other inſects: for the Weevils which I am now treating of were all alive the preceeding ſummer.

As to the two maggots which I at firſt found in the glaſs among the wheat, I had no doubt that they had fallen out of the grains wherein they had been firſt depoſited, by reaſon that thoſe grains had been rather too much eaten away before the eggs were laid in them, and the holes which had been made in them rather too large; and, as all creatures, however minute, are endowed with moſt admirable faculties and powers to anſwer the ends of their creation, I think it very probable that the large trunk or beak with which this inſect is provided, (furniſhed with teeth or pincers, which open and ſhut in exact correſpondence with each other,) is given to it of ſuch a length that it may be enabled to bore a ſmall deep hole in every grain of wheat, and therein depoſit an egg, otherwiſe the maggots breeding from theſe eggs would never grow to maturity: for if a Weevil were to lay its egg on the outſide of a grain, and a maggot ſhould be hatched from it, ſuch a maggot could not poſſibly pierce the huſk of the wheat. Again, were a Weevil to lay more than one egg in one grain, and all theſe eggs produced maggots, they would hinder each other's growth, for want of having ſufficient nouriſhment, inaſmuch as one grain is not more than ſufficient to nouriſh one maggot, and ſo to produce one Weevil.

I obſerved in opening one grain in which a ſmall hole had been made, and out of which I took one ſingle egg, that round about that part where the egg was placed, the mealy ſubſtance of the wheat had been looſened or reduced to powder, from whence I concluded that the parent Weevil, before it laid the egg, had by means of its trunk, ſeparated the particles of meal in that part, both to make a

ſoft place for the egg to lie in; and alſo, that when the minute maggot ſhould creep out, it might find this ſoft and looſened meal prepared for its firſt feeding on.

Some of theſe maggots I placed in glaſſes by themſelves, and obſerved them gradually to aſſume the form of Weevils, the beak, horns, and claws, appearing by degrees, and the colour alſo changing from a white to a yellow, and then to the red colour of the Weevil.

As I had obſerved, that none of theſe inſects which were kept in glaſſes together with grains of wheat, ever depoſited their eggs on the glaſs, I put three females into a glaſs by themſelves, and in the ſpace of twenty-four hours they laid four eggs. One of which eggs drawn from the microſcope, is repreſented in Plate II. *fig.* 1, A B C. In the ſpace of ſeven days theſe eggs produced the kind of maggots before mentioned, which, when firſt hatched, were not larger than a grain of ſand, and one of theſe as lying on its back, and drawn from the microſcope is repreſented at *fig.* 2, wherein D E F, is the head and F G D the body. This maggot was in continual motion, but when a little at reſt, it contracted its body together, and in this poſition the limner drew its figure, and when it attained to its full ſize, the ſhape remained the ſame until the time approached for its being changed into a Weevil. Another maggot which I had fixed or faſtened by its hind part before the microſcope, I cauſed to be drawn when it extended its body, and this is ſhewn at *fig.* 3, H I K.

Theſe maggots have very little ſtrength to move from place to place, ſo that it ſeems deſigned by nature, that they ſhould be fed no where but in grains of corn: for if a Weevil were to depoſit its egg in any place, except in the inſide of a grain, it would in my opinion, be impoſſible for the maggot thence produced to procure any nouriſhment and become a perfect Weevil.

Theſe things conſidered, we may be fully ſatisfied reſpecting the

reaſon, why in corn, which is frequently moved and ſhifted, the Weevil can increaſe but little: for ſuppoſing one of theſe inſects to have pierced and prepared two or three grains ready to depoſit its eggs, and ſoon afterwards the corn is moved or ſpread about, the animal, when it is ready to lay an egg, finding no grain prepared to receive it, muſt leave ſuch egg on the outſide of the corn, where the young maggot, when hatched, will be in the ſame ſituation as ſeed ſown in barren land, and conſequently muſt periſh. But if ſuch corn is undiſturbed, the Weevil may multiply, in a great degree, by depoſiting its eggs in the grains fitly prepared for them, and which may be conſidered as ſo many neſts for the reception of the young. Again, the long life of this inſect cauſes it to multiply exceedingly, for the Weevils which I received in the month of March, (the youngeſt of which was undoubtedly a year old,) were alive and vigorous in June following; and who can tell how long the natural life of this inſect may be?

For the information of thoſe who never ſaw a Weevil, one of theſe inſects is repreſented of its natural ſize at *fig.* 4, X, and underneath it, I have given a drawing of its beak or trunk, as ſeen by the microſcope, to ſhew by what organs or inſtruments this creature is enabled to pierce the corn, partly to feed on the contents, and partly to depoſit its eggs in the ſmall holes it makes therein: for, as other animals are taught by nature to prepare their neſts for the reception and ſupport of their young, ſo it is the peculiar inſtinct of the Weevil to aim at depoſiting its eggs in no other place than where the little animals produced from thoſe eggs ſhall be able to find ſubſiſtence, and this is in the grains of corn.

At MNOP is repreſented the proboſcis, trunk, or beak of the Weevil, which naturally is not ſo ſtraight as here pictured, but appears bent downwards when ſeen ſideways, as marked at M Q O; but had the figure been drawn in that view, the opening at the ex-

tremity with its pincers or teeth would not have been viſible, as it is now to be ſeen at O: within this mouth or orifice are two ſtings or piercers which are continually in motion and one of which is ſeen in the figure, but I never obſerved the animal to protrude or thruſt thoſe ſtings or piercers farther than the extremity of the pincers at O; ſo that I imagine the only uſe of theſe organs is to break or divide the huſks of the wheat and the meal within it; and, having frequently contemplated this animal, while feeding, I obſerved it, after having thruſt its trunk into a grain of wheat, to ſtick ſo cloſely to it, that, though toſſed about, it would not let go its hold.

S T, are the two horns; L M R, is part of the head; and at M are repreſented* a collection of globules, which through the microſcope exhibit the ſame appearance as if by the naked eye we were to ſee a parcel of very minute black coral beads placed in exact order cloſe together; and this I concluded to be one of the eyes.

I am not very fond of drawing the whole bodies of ſmall animals from the microſcope, becauſe I conſider that to be of little utility; and this is the reaſon why I have only given a figure of part of this inſect when magnified.

I truſt that theſe experiments and obſervations will prove that Weevils cannot be produced, otherwiſe than by propagation, that is to ſay, by copulating and laying eggs, from which eggs maggots proceed; and finally those maggots are changed into Weevils. But whether the vulgar will be hereby convinced of the error of their opinion in this reſpect, I much doubt, being continually peſtered with their objections to what I have advanced. It is, however, with me, a moſt certain truth, that what I have demonſtrated reſpecting the

* To thoſe who have not been much converſant in theſe objects, it may ſeem ſtrange that a collection of globules or little balls ſhould conſtitute but one eye; but ſuch readers will be pleaſed to underſtand, that in moſt inſects, each eye is formed of a great number of ſmaller optical organs, or eyes, and this ſubject will be found amply diſcuſſed in the courſe of this work.

Weevil, namely, that it cannot be produced otherwiſe than by generation, does alſo hold good with regard to all creatures endued with life and motion. And although this is a very minute animal, yet its ſpecies muſt have been continued in the way I have laid down, from its firſt being formed at the creation: and were it otherwiſe, namely, that from inanimate matter, ſuch as ſtones, wood, earth, plants, or ſeeds, this or any other animal ſhould be produced, that would be a departure from the general courſe of nature; and ſuch formation or new creation, muſt be continually derived from the ſupreme Almighty Creator.

Probably what I here advance may appear ſtrange to ſome, and they may perhaps wiſh me to enquire into the propagation of other minute animals; but for the preſent I leave the proſecution of theſe matters to thoſe who may chuſe to beſtow as much labour thereon as I have done in this examination of the Weevil, aſſuring them that my obſervations are the reſult of more than four months application to the ſubject.

Of the Maggot or Caterpillar infeſting Corn in Granaries; the nature of its generation explained, and the means to prevent its increaſe pointed out.

HAVING, as I hope, by my obſervations on the Weevil, convinced mankind, that it is propagated in the ordinary way of generation, I have ſince employed myſelf in the examination of that Inſect or maggot which our bakers and corn dealers name "*de Wolf.*"*

This creature is a very ſmall white maggot, provided with two red pincers, or organs like teeth, placed in the fore part of its head, by which it not only feeds on, and conſumes wheat, and other grain, but alſo can perforate or gnaw holes in wood. The common opinion is, that it is produced from corruption, or elſe from what ſome call a blight. But, in order to refute this vulgar error, I procured from a Merchant, a box of wheat, in which this inſect abounded, that I might diſcover to all, the real manner of its propagation.

Upon inſpecting this wheat, I found, that one ſingle maggot had ſtuck or faſtened together from five, to ſix, ſeven, or even eight, grains of wheat, in one of which itſelf was concealed, and that moſt of the other grains were hollowed or ſcooped out in the middle; and it ſeems to me that this maggot is much more pernicious than

* That is, in Engliſh, "the Wolf." This Inſect is not much known in England among the country people, for the Tranſlator having procured from an Importer of Corn, a ſample of Pruſſian wheat infected with it, and ſhewn it to ſeveral farmers, the appearance ſeemed new to them, nor could they aſſign to the animal any name in Engliſh. But to the Dutch, who have always been great importers and exporters of corn, it ſeems to have been familiar, and the Author's remarks on this ſubject may be well worthy the attention of our Engliſh merchants.

the Weevil, becauſe it ſcatters a great quantity of its excrements in the ſhape of white round balls, which are very large in proportion to the ſize of its body.

Moreover, this maggot has in the anterior, or fore part of its head, an organ, or inſtrument, through which it continually ſpins an exceeding fine thread, which thread it fixes to every ſubſtance it approaches. By this means its body is always ſupported ſo that it cannot fall, and in a clean glaſs it can move from place to place, being ſuſpended by this thread, and by this thread alſo it connects or binds the grains of wheat together.

Some of this wheat I put into a glaſs tube, about the ſize of a finger, and a foot in length, cloſing each end with a good ſtopper, and the reſt of the wheat I kept in a wooden box. But, towards the end of the ſummer, I obſerved ſeveral of the maggots forſaking the wheat, and faſtening themſelves to the glaſs, and others of them I ſaw creeping about among my papers, and I found the box, in which I had put them, perforated in two places, through which many of them had eſcaped. I alſo ſaw the ſtopper to the glaſs tube gnawed into, as deep as the thickneſs of a finger, and upon taking it out, I found that eight or ten of the maggots had crept into it; upon which I placed them again in the glaſs tube, with the grains of wheat, and ſtopping the orifices with a cork, I covered the cork on the outſide with ſealing-wax, to prevent the maggots again eſcaping, but at the ſame time I contrived a ſmall aperture that they might not be deprived of air. Plate II. *fig.* 5, A B C D repreſents this glaſs tube, of which A D, and B C are the two extremities, each cloſed with a ſtopper covered with ſealing-wax; E G and F H are two ſmall glaſs tubes, paſſed through the ſtoppers, to ſupply the maggots with freſh air, but thoſe apertures were ſo ſmall as not to permit their eſcape.

About the ſame time that I was employed in theſe obſervations, I viſited a granary infeſted with this inſect, and ſaw the maggots, in great numbers, creeping up the walls, from whence I concluded,

that in like manner as the maggots in the glaſs tube quitted the wheat, and lodged themſelves in the ſtoppers, ſo in the granary they concealed themſelves in the linings and beams, until their transformation into flying inſects ſhould be compleated. And I was confirmed in this opinion by obſerving the granary to have been ſo perforated, or eaten into by theſe maggots, that not a fingers breadth was left untouched by them.

I alſo obſerved that great part of the ſtopper which was within the glaſs tube, was gnawed or reduced to powder, and many chinks or crannies formed in it, and though the maggots endeavoured to conceal themſelves within the ſtopper, yet three of them remained in the glaſs, in which they lay quiet the whole winter, and they were ſo little covered with their web or thread, that, with the microſcope, I could diſcover them move their heads.

On the 29th of April following, I ſaw them begin to aſſume a reddiſh colour, and to be ſomewhat contracted in length; the next day the redneſs increaſed, and they ſeemed to me to be turned into aurelias.

At the ſame time, upon examining the wheat, which was kept in the box, and had been full of the maggots, I found that they had all eſcaped through the holes perforated by them in the box.

On the 23d of May, the aurelias before mentioned, had become of a red colour, and the next day I ſaw a flying inſect, which is called a Moth, fluttering about the glaſs tube. This had proceeded from one of the aurelias, which had been the chief ſubject of my obſervations, and I ſaw lying near it, a pellicle, or little ſkin, which had been the caſe or ſheath in its aurelia ſtate.

Two days before diſcovering this moth, I had obſerved ſeveral of the ſame winged inſects flying about my ſtudy, two of which I killed, and upon examining them by the microſcope, I found them to be formed in the ſame manner with this in the glaſs, ſo that I was convinced they had proceed from ſome of the maggots which had eſcaped

out of the box. And on the 25th of May I ſaw two more moths come out of the ſtopper to the tube, leaving their ſhells or caſes hanging to it.

As many perſons are unacquainted with the figure of theſe moths, I have cauſed a drawing to be made of them, which is to be ſeen at *fig.* 6, A A; and alſo a drawing of the covering, ſhell or caſe which encloſes them while in their aurelia ſtate, *fig.* 7, P Q. Theſe figures were drawn of the natural ſize, and if I had not had ocular proof of it, I could not have believed it poſſible for the moths to come out of ſo ſmall a caſe or covering as is here pictured. *

On the ſame 25th of May, I went to the granary, where, the preceding autumn I had ſeen the maggots before mentioned creeping up the walls, and there I ſaw a number of moths, ſome clinging to the wall, and others flying about. I had brought with me ſix glaſs tubes, and, as it was eaſy to diſtinguiſh the males from the females, the former being ſmaller than the latter, I put in each of theſe glaſſes ſome of both ſexes.

At my return home, I diſſected three of theſe females, and, by the moſt accurate reckoning I could make, I found in each of their bodies upwards of fifty eggs. At another time, I judged that I took out of another female moth, above ſeventy eggs. Theſe eggs were exactly the ſhape of hens eggs, but no larger than ſmall grains of ſand. The reſt of the moths which I had brought from this granary and kept alive, laid many eggs, and one of them produced to the number of ſeventy.

I next conſidered, whether the moths, which thus propagate the

* This obſervation of the Author is corroborated, and, at the ſame time, the appearance can be accounted for, by a circumſtance which was ſome years ago communicated to the tranſlator by a curious obſerver of the change of aurelias into butterflies and moths, namely, that immediately after their emerging from the ſhell, or covering, which incloſes them, they increaſe in ſize ſo rapidly, particularly in the wings, that their growth may be diſcerned by the eye.

pernicious inſect I am treating of, might not, by ſome means, be deſtroyed in the granaries, ſo as to prevent their propagation.

For this purpoſe I took a round glaſs veſſel, large enough, as I ſuppoſed, to hold ſix pints of water, and in it I put eight living moths newly taken. In the orifice of this veſſel I ſet fire to the fourth part of a grain of ſulphur, and as ſoon as the moths began to feel the vapour, or ſmoke of the ſulphur, they fluttered about the glaſs with great violence, though but for a ſhort time, for they all fell to the bottom, and after a little motion in their feet, they died. Four hours afterwards, I took them out of the glaſs, and put into it ſome freſh ones alive, in order to repeat the experiment, but while I was preparing to burn the ſulphur, I ſaw them all lie dead, they having been killed with the bare odour of the ſulphur which had been left in the glaſs.

From the ſize of this glaſs, I computed what quantity of ſulphur would be requiſite to fumigate a granary twenty four feet long, ſixteen broad, and eight feet high, and I reckoned that half a pound would be ſufficient for the purpoſe.

After this, I fumigated a granary, in which were eight loads of wheat, and a great number of moths flying about. For this purpoſe I took two pieces of ſulphur, containing about a quarter of a pound, prepared in the ſame manner as is done by wine-merchants or coopers, to fumigate their wine caſks. Theſe pieces of ſulphur I ſuſpended by a braſs wire, in a tall earthen veſſel, with a narrow top, and placed the veſſel in an earthen diſh, to prevent any danger of fire. This apparatus I ſet in the middle of the wheat, and as ſoon as the ſulphur began to burn, I retired out of the granary and ſhut the door. In a large granary two or three of theſe veſſels might be uſed.

Two days afterwards, I viſited the granary, and then I ſaw ſeveral moths ſtill clinging to the wall and beams, but before the fumigation, I believe there were ten times as many. And I accounted for theſe moths being found alive, either becauſe many of the panes of

glaſs in the windows were broken, through which much of the ſmoke of the ſulphur had eſcaped, or elſe, that the moths which I now ſaw, had come out of their aurelia ſtate after the fumigation was over; for I am well aſſured, that ſo long as the moths are incloſed in their aurelia caſe, or covering, the ſmoke of ſulphur cannot do them any injury. Therefore it will be neceſſary for thoſe who may chuſe to fumigate their granaries in the manner I have recommended, to begin the operation as ſoon as ever the moths appear, that they may be prevented laying their eggs, and alſo to continue the uſe of it ſome days, indeed as long as any moths are to be ſeen, becauſe theſe creatures do not all come out of their aurelia ſtate at the ſame time. The expence of fumigating is no object, for a pound of ſulphur may be bought for a trifle, and it is in no ſort injurious to the wheat, nor is it prejudicial to the health of any perſon, but rather ſalubrious.*

Towards the end of ſummer, when the maggots quit the wheat, and creep up the walls, they may eaſily be ſwept down and deſtroyed, for this inſect is a very tender animal, and ſoon killed. And theſe precautions being obſerved, very few moths will be ſeen the following year.

Some of the eggs laid by theſe moths I put in glaſſes by themſelves, which I carried about in my pocket, others of them I placed in my ſtudy, and I obſerved that thoſe which I carried about me were, by the heat of my body, much ſooner hatched than thoſe which were in my ſtudy, for theſe latter were ſixteen days before the maggots crept out of them; but at ſeven days end thoſe in the former made their appearance.

One of theſe maggots, when newly hatched, I put into a glaſs tube, the inſide of which was about the fifth part of an inch wide, and having placed this before the microſcope, I gave it to the limner

* This opinion is confirmed by Dr. Hodges, and Dr. Mead, in their Treatiſes on the Plague.

to make a drawing of, but as it was impoſſible for him to draw all the minute parts of it, he drew it without the feet, as is ſhewn in *fig.* 8, K L.* The fore part of this maggot is provided with ſix feet, which ſometimes could be diſcerned when the animal lay flat on its belly, and theſe, with part of the body are ſhewn at *fig.* 9, M N. In the hind part are various organs aſſiſting in its motion. This maggot, although, when newly hatched it appeared no longer to the naked eye than is deſcribed in the center of the circle at *fig.* 10, was yet twice the length of the egg from which it was produced.

As I obſerved ſome of theſe young maggots to be dying, I put ſome grains of wheat into the glaſs, and ſoon afterwards the living ones diſappeared, whence I concluded that they had found their way into the wheat, and in three or four days time I ſaw their excrements ſcattered about the glaſs.

I have often contemplated the ſhells of the eggs from whence theſe maggots proceeded, and obſerved veſſels in them in the nature of net work, which I could not diſtinguiſh while the eggs were full. A drawing of one of theſe is given at *fig.* 11, R S T V, but as theſe eggs are exceedingly minute, this drawing was made from a microſcope of greater magnifying power than that from which the former figures are drawn. S T V is the broken ſhell of the egg in the part where the young maggot crept out.

The moths I have been deſcribing are very pretty objects to behold, the wings, which are four in number, being white, ſprinked all over with black ſpots; and on examining them by the microſcope I found that this whiteneſs proceeded from the white feathers on the wings, and that the black ſpots were cauſed by other feathers which were black at the edges. Some thouſands of theſe feathers

* This figure does not ſeem taken with ſo much exactneſs as is generally found in thoſe given by Mr. Leeuwenhoek, therefore the Tranſlator has cauſed a drawing from one of the maggots when full grown, to be made of the ſame ſize it appears to the naked eye, and this is to be ſeen at *fig.* 12.

I ſaw ſticking to the glaſſes in which I kept the moths, which in their fluttering againſt the glaſs or one another, had been rubbed off their wings and other parts of their bodies; and to the naked eye, exhibited the appearance of a vapour or ſmoke on the glaſs.

Though I examined ſome thouſands of theſe feathers, they were all ſo differently formed, that I cannot ſay I ſaw two exactly alike. *Fig* 13, AB, CD, EF, repreſents three of the largeſt of them, when ſeen through the microſcope. At their broad ends, they are tinged with black, and when ſeveral of them lie cloſe together, they exhibit a black ſpot. Others of theſe feathers, as *fig*. 14, GH, IK, LM, are tranſparent, but when lying one on another they produce the whiteneſs I have mentioned. All of them, although ſo very minute, have quills like the feathers of birds, by which they are fixed or rooted in the membrane that forms the wing, and ſo completely cover it that it cannot be ſeen.

The feathers, which cover the edges of the wings, are much longer than the others, and of different ſhapes; five of them are repreſented at *fig*. 15, RS, TVW, and at *fig*. 16, NOPQ, are ſhewn a number of the ſmall feathers of different ſhapes.

This maggot, which among us is called the wolf, is not only miſchievous, by devouring the corn, but it is of that ſpecies which is found in houſes, and gnaws holes in wood, alſo in boxes and books, and likewiſe hides itſelf in woollen garments, eating holes in them, and at length becomes a flying inſect, named as before mentioned, a moth.

This moth, of itſelf, is very innocent, for while in that ſtate, it does not, as I could diſcover, take any food, but, if not deſtroyed in time, one female may produce ſeventy maggots, for out of upwards of ſeventy eggs, laid by one moth, I only ſaw one barren; and in three others of the eggs, I could diſcern the maggots lying dead, by reaſon, as I ſuppoſe, that they could not break their ſhells.

I heard it affirmed, by a corn-dealer, in ſupport of his opinion,

that theſe maggots are produced in wheat ſpontaneouſly, that they are more rarely found in old wheat than in new; to which I gave for anſwer, that when firſt hatched, they are very ſmall and tender, ſo that it is difficult for them to pierce the huſk of old wheat, the ſame being very dry and hard, and conſequently many of them die for want of nouriſhment. This I fully proved by experiment, for I had three glaſſes ſtanding in my ſtudy, in one of which there were more than ſixty maggots newly hatched. In this glaſs I put ſome grains of wheat, one of which was broken, or ſplit down the middle, and this alone was eaten into, the others remaining uninjured, and all the maggots, except one or two, died; all which, I had no doubt, proceeded from this, that theſe grains of wheat were remarkably dry and hard, having been kept for two or three years in a box in my ſtudy. and in another of the glaſſes, wherein I obſerved the maggots creeping about on the ſurface of the wheat, without being able to penetrate it, I cut ſeveral of the grains in pieces, and by this means many of the maggots were kept alive.

Towards the end of the month of September, I received from a baker a handful of very excellent rye, with many of theſe maggots in it, all which I put into a large glaſs veſſel, and I obſerved the maggots quit the rye and creep up the ſides of the veſſel. I then burnt a ſmall quantity of ſulphur in it, and in a ſhort time they were all killed.

It may not here be unworthy of notice, that, in the glaſs tube before deſcribed, and in which I imagined I had put nothing except wheat, and the caterpillar or maggot, of which I have been treating, I found a Weevil make its appearance: this creature I kept in the glaſs to ſee if any more would appear, and I obſerved, that in the winter or in cold weather it lay motionleſs as dead, but upon applying ſome warmth, it would revive. At length, after keeping it upwards of eighteen months, in which time, I did not obſerve any more of the ſpecies, it died.

Moreover, while I was examining the granary before mentioned, I ſaw many very minute animalcules*, no bigger than grains of ſand, creeping up the walls. Some of theſe I brought home with me in glaſſes, and I obſerved them to couple together, and to lay exceſſively minute eggs, which eggs, after ſome time, produced animalcules formed like the parents. By this it appears that theſe little creatures propagate their like, without undergoing any ſuch change as is obſerved in fleas, moths, flies, and many other inſects: I think, however, it is fully proved, that no living creature is produced from corruption or putrefaction.

Indeed, can any man in his ſober ſenſes imagine, that the moth, of which I have given the deſcription, which is fitly provided by nature with the means to propagate its ſpecies, furniſhed with eyes exquiſitely formed, with horns, with tufts of feathers on its head, with wings covered with ſuch multitudes of feathers, all of different ſhapes, and theſe exactly covering the wings in every part; can this moth, I ſay, adorned with ſo many beauties, be produced from corruption? For, in a word, in this little creature, contemptible as it ſeems to us, there ſhine forth ſo much perfection and ſkill in the formation, as to exceed what we obſerve in larger animals.

* Mr. Leeuwenhoek has not given any figure of theſe animalcules, but they ſeem to be a ſpecies of mite: the tranſlator has obſerved ſome of the like kind in bran.

OF THE SPIDER.

THE following obſervations were made on thoſe kinds of Spiders which are found in gardens; where they fix their webs to vines, herbs, and ſhrubs.

I have often ſeen theſe Spiders, when dropping, or falling, as it ſeemed, from a tree, ſtop or ſupport themſelves in the midway, by means of their thread, and I found that this was done by the help of one of their hind feet, which they continually apply to the thread as they ſpin it. Theſe feet are each of them furniſhed with three nails or claws, ſtanding ſeparate, or apart from each other. Two of theſe claws are at the extremity of the foot, and each of them is formed with teeth, or notches, like the cuts in a ſaw, growing narrower towards the bottom; and with theſe they are enabled to hold faſt the thread, in like manner as the pulley or wheel, uſed by clock-makers, in their thirty-hour clocks, is contrived to lay hold of the clock-line, by means of the groove being narrower at bottom. For the more perfectly underſtanding this formation, I cauſed the following figure to be drawn.

Plate II. *fig.* 17, A B C D E F, repreſents a ſmall part of the Spider's hind foot, magnified, and at B C D, are ſhewn the two claws, or nails, with the notches or teeth in them, as before deſcribed: at letter E, is ſeen the third claw, which is deſtitute of teeth or notches, but, as I conceive, ſerves for various uſes to the animal, and this is always to be noted, that when the Spider does not want to aſcend to an height, but only to lay hold of the web it has ſpun, it always uſes this claw for that purpoſe.

The kind of Spider I am now deſcribing, has the hind part of its body much larger than is ſeen in other Spiders; it is provided with eight longer and two ſhorter legs, which ſhorter ones are placed in the fore part of its body on each ſide of the head, and all furniſhed with an indented or notched claw as before deſcribed. Some will have it, that Spiders have no more than eight legs, but this appears to be a miſtaken opinion.

In theſe Spiders I plainly perceived eight eyes, two of which are placed near to each other at the top of the head, and, in my judgment, deſigned to ſee thoſe objects which are above the animal. Two others of them are ſituated a little lower down, in order to diſcover all objects in front; and on each ſide of the head are a pair of eyes cloſe to each other, and of theſe, the two which ſtand forward, are to take in the view of all objects lying obliquely, or not ſtraight in front; and the two which ſtand backward, are undoubtedly deſigned to behold all objects behind the animal. And if we conſider that the pupils of theſe eyes are immoveable in the head, we may eaſily conclude, that this number is neceſſary, for enabling the Spider to behold all circumjacent objects, and to go in ſearch of its food.

That the form of theſe eight eyes, and their ſituation, may be more eaſily conceived, I have cauſed a drawing to be made of them at *fig.* 18, GHIKLMNO, which repreſents a part of the Spider's head; PQ, are the two eyes which look upwards, K and L, the two deſigned to view objects in front, I and M, thoſe which take in objects obliquely in front, and H and N thoſe which look obliquely backwards.

I have often heard it ſaid, that the Spider has a ſting, with which, it is alſo reported, it can kill the toad; but no one could tell me in what part of the body this ſting was placed, therefore, I concluded that if there was one, it muſt be in the poſterior or hind part, as in other animals and inſects; but on examination, I found this opinion to be groundleſs. The Spider is, however, provided with two

organs or weapons anſwering every purpoſe of a ſting, which are placed in front of its head juſt below the eyes, and when not in uſe, they lie between the two ſhorter feet.

Theſe weapons or inſtruments of offence, which are bent in the nature of claws, are very ſimilar to the ſting of the Scorpion and the fangs of the *Millepeda of India, and in each of theſe fangs (for ſo I will call them) is a ſmall aperture, through which, in all probability, a liquid poiſon is emitted by the Spider at the time it inflicts the wound.

At *fig.* 19, ABCDEFGHIKLM, are repreſented both theſe fangs as ſeen through the microſcope: BC, is one of them when lying ſtill, HIK ſhews the other, raiſed to ſtrike. At C and I, is to be ſeen the ſmall aperture† I have mentioned, which aperture appears the ſame on both ſides of each fang, and through this we may reaſonably conclude that the Spider ejects its venom. At the letters EFG, is a double row of teeth, between which each fang is placed when at reſt, and the uſe of theſe teeth ſeems to me to be for the firmer graſping the prey, that when bitten it may not eſcape. All the other parts of theſe weapons or organs which are repreſented in *fig.* 19, were thick ſet with hairs, but which it was not thought neceſſary to exhibit in the drawing.

I at ſeveral times incloſed two or three large Spiders in the ſame glaſs, and always found that when they approached each other, they

* That is in Engliſh, thouſand legs, the name vulgarly given to this animal; the Dutch call it Duyſent-been, a word of the ſame import.

† Dr. Mead, in his celebrated Eſſay on Poiſons, when treating of the Spider, expreſſed his doubt of this fact, by reaſon that he could not himſelf diſcover the aperture, and Mr. Henry Baker, in his Treatiſe on the Microſcope, concurred in opinion with the Doctor, that Mr. Leeuwenhoek muſt have been miſtaken in this particular. But in another Treatiſe*, afterwards publiſhed by Mr. Baker, he informs his readers, that he had at length plainly perceived the aperture, and had ſhewn the ſame to Dr. Mead, who was much pleaſed with the diſcovery. A teſtimony this, greatly to the honour of our Author.

* Employment for the Microſcope.

would fight to that degree, as to be covered with the effuſion of blood from their bodies*, which was ſoon followed by the death of the wounded Spider. I alſo obſerved, that the ſmaller Spiders always avoided the larger, but when two of nearly equal ſize approached each other, neither would give way, but both of them grappled together furiouſly with their fangs, till one of them lay dead upon the ſpot, its body being as wet with the blood flowing from the wounds received, as if water had been poured upon it.

I at one time had a Spider which was wounded by the bite of another in the thickeſt part of its leg, and from the wound there iſſued ſome blood, in quantity, about the ſize of a large grain of ſand; this wounded leg, the Spider held up, as unable to uſe it, and ſoon afterwards the whole leg dropped from its body: whenever the breaſt or fore part of the Spider was wounded, I always obſerved the wound to be mortal.

I had imagined, that when a Spider applied its thread either to ſome foreign ſubſtance or to another thread, that the thread newly ſpun muſt be covered with ſome viſcous or glutinous matter by which it became faſtened, in like manner as we obſerve in Silk-worms threads. But I now found that the Spider cannot fix its thread to any thing, without imprinting the hind part of its body on the place, by which preſſure, it emits an incredible number of exceſſively ſmall threads, diverging in every direction, from whence we may conclude, that as ſoon as the threads are expoſed to the air, they loſe their viſcoſity or glewy quality.

When I at firſt began the diſſection of the Spider, and endeavoured to diſcover the viſcous or gummy ſubſtance from whence theſe threads proceed, and could not ſatisfy myſelf in that particular, I was aſtoniſhed, not being able to conceive how, from ſo moiſt a

* If any reader ſhould be diſpoſed to try this experiment, he muſt not expect to ſee a red liquor iſſue from the wounded Spider. For the circulating fluid in many inſects is clear or colourleſs, though as fitly to be denominated blood, as that which flows in the veins of animals.

body as this creature's, there could in ſo ſhort a time, be produced threads ſtrong enough to bear the weight, not only of one, but of ſix Spiders at a time. And upon endeavouring to diſcover the texture of the threads, I could at that time perceive no more, than that the ſame thread appeared in ſome places to be one and entire, and in others, to be compoſed of three, four, or more threads; and though I often endeavoured to obſerve thoſe threads immediately as they iſſued from the Spider's body, I could not obtain a perfect view of them, notwithſtanding which, I did not doubt, that what is commonly ſuppoſed to be one thread, is, in fact, compoſed of many.

I determined therefore, ſo to fix a Spider on its back, that it could not move the hind part of its body; and this being done, I contrived with a ſmall pair of pincers to draw out from the body, that ſmall part of the thread which projected from the organ or inſtrument from which the threads proceed, and then I perceived a great number of exceeding ſmall threads iſſue forth, which, when at about one or two hairs breadth diſtance from the Spider's body, united in one or two threads, and that in this manner the larger threads were compoſed.

Not content with theſe obſervations, I ſat about deviſing means of keeping the threads ſeparate, as they iſſue from the Spider's body, ſo that I might be able to give ſome repreſentation of their inconceivable fineneſs, and at three ſeveral times I ſucceeded herein to my wiſh. But yet, this fineneſs cannot by any efforts of the pen or pencil, be adequately deſcribed. For upon applying the utmoſt magnifying powers of the microſcope, threads are diſcovered ſo exquiſitely ſlender, as almoſt entirely to eſcape the ſight. I have ſometimes endeavoured to count theſe threads as they iſſued forth, but always without ſucceſs.

The Limner, to whom I exhibited this object by the microſcope, declared, that it was not in his power to give a true drawing of it

with the pencil, but that by an engraving, it might in ſome meaſure be repreſented. This is done in *fig.* 20, M N O P Q, being a portion of theſe threads, as magnified by the microſcope, and pictured ſeparate and diſtinct from each other, as they iſſued from the body of the animal. Theſe ſeemed to me to iſſue from two of the organs, which I ſhall preſently deſcribe.

If we duly conſider that the threads of Spiders, which to the naked eye ſeem to be ſingle, are compoſed of many ſmaller ones, and that they thence acquire the ſtrength we obſerve them to have, we ſhall more than ever be aſſured, that no flexible bodies (except thoſe made of metal, the component particles of which are, by the force of fire, moſt cloſely compacted or knit together), can have any great ſtrength or toughneſs, unleſs they are compoſed of oblong parts laid ſide by ſide, and that their ſtrength or toughneſs will be greater where theſe oblong component parts are twiſted together, or made to cohere by ſome glutinous matter, as are ſpun ſilk, linen garments, ropes and the like. And this is the reaſon why all the ſingle threads of flax are very tough in proportion to their ſize, for each of them is compoſed of ſtill ſmaller particles or fibres, which are not only joined together by a certain viſcous or gummy matter, but are alſo ſurrounded with a coat or bark, as it may be called, whereby their inward component fibres are rendered ſtill ſtronger

Again, if we advert to the great number of exceſſively ſlender threads, proceeding, all at the ſame time from the body of the Spider, we muſt acknowledge that this kind of formation is neceſſary, for were it a ſingle thread which is ſpun by this creature with ſuch celerity, the liquid matter of which it is formed, could not on its expoſure to the air, become a ſolid ſubſtance ſo quickly as theſe leſſer threads; an hundred or more of which, taken together, do not in my opinion equal the hundredth part of one of thoſe hairs I can take from the back of my hand.

In a word, the inſcrutable power and wiſdom of the Almighty Creator, are manifeſtly diſplayed in the formation of ſuch a thread as the Spider's, the wonderful make of which is ſeldom obſerved, becauſe the fineneſs and delicacy of its texture are not diſcernible by the naked eye.

Upon beholding the exquiſite ſlenderneſs, and alſo the multitude of theſe threads, I was ſtruck with aſtoniſhment, upon conſidering how wonderful muſt be the organs in a Spider's body to produce ſo many, and at the ſame time all diſtinct from each other. And although I never expected that I ſhould be able to dive into this ſecret of Nature, yet, upon diſſecting the hind part of one of the largeſt Spiders I could procure, and attentively examining it, I at length, with the greateſt admiration, perceived a great number of exceſſively ſmall organs, from each of which, one exquiſitely fine thread proceeded, and theſe were ſo many, that I thought their number muſt at leaſt exceed four hundred. They were not all placed cloſe together, but in eight diſtinct ſpots or compartments, ſo that if the Spider uſes all theſe organs at the ſame time, eight ſeveral threads may be formed, each of which will conſiſt of a great number of ſmaller ones. Again, theſe ſmaller threads differ in ſize, for one of the organs will be ſeen to ſpin a thread twice as large as the next adjoining to it.

If any perſon examines by the microſcope that part towards the extremity of the Spider's body, from whence its thread proceeds, he will obſerve the ſpot to be, as it were, ſurrounded by five ſeveral protuberances or riſings, each ending in a point, and altogether forming a kind of encloſure; but from the anterior or forwardeſt of theſe five protuberances no threads proceed. The other four, on their outer ſides are thick ſet with hairs, ſo that all the ſmaller organs deſtined to ſpin the threads, are ſituated towards the inſide, the reaſon of which, I take to be, that they may be preſerved uninjured,

when the Spider is creeping into holes, where it does not want to ſpin its web, or while running along the ground, or after its prey. When theſe laſt mentioned four protuberances are put aſide from each other, there will be ſeen in the middle or ſpace between them four ſmaller ones, each furniſhed with the like organs for ſpinning threads, but leſſer in ſize and fewer in number.

Theſe organs for ſpinning, being by this means all expoſed to view, exhibit the appearance, as it were, of a field, thick ſet with an incredible number of pointed parts, each producing one thread; but theſe pointed parts are not made gradually tapering from the baſe to the point; they are formed, as if one were to imagine a ſmall reed ſomewhat tapering, having a ſtill ſmaller one joined to its taper end*, and this latter terminating in a point, which point, in theſe organs I am now deſcribing, is as fine as imagination can conceive.

Now if we lay it down as a fact, that a young Spider which is ſeveral hundred times ſmaller than a full grown one, is furniſhed with the ſame organs as the larger, and that, as the Spider, ſo the organs do by degrees grow proportionably larger, the neceſſary concluſion is, that the threads ſpun by a young Spider, are many hundred times finer than thoſe ſpun by one full grown, which exquiſite ſlenderneſs, it ſeems beyond the power of the human mind to form a true idea of.

I have given a repreſentation of ſome of the organs, by which theſe incredibly ſmall and numerous threads are ſpun, as nearly as the Limner was able to draw them, when ſeen by the microſcope. And, at *fig.* 21, RSTV, exhibits one of the four external parts or protuberances I have been deſcribing; this part, including all which with it is repreſented in the figure, was not in its natural ſize ſo large as a common grain of ſand, from whence ſome judgment may be formed how minute muſt be theſe organs, and how exquiſitely fine the threads which iſſue from them.

* See *fig.* 22.

In this figure, that part which is marked with the letter W, was covered with as many organs, and thoſe placed as cloſe together, as are repreſented between the letters R and S, but as theſe latter, ſtanding directly in front, could not by any means be diſtinctly ſhewn in the drawing, I ordered that ſpace to be left vacant: the part which is out of ſight, was not covered with theſe organs but with hairs.

While I held this object up to the Limner's view, I turned round the different parts of it, that he might declare how many of the organs for ſpinning the threads, in his judgment, it contained, upon the view of which, he was confident that there were above one hundred.

I have before mentioned, that ſome of theſe organs appeared to me to be larger than others, and that I ſuppoſed their uſe was for ſpinning the larger threads. One of theſe, as it ſtood between two ſmaller ones, I placed in view of the Limner, directing him to make a drawing of it. This is ſeen at *fig.* 22, C F, and in the ſame figure, at the letters A B and D E, are repreſented the two leſſer organs, from one of which, a thread is ſeen to iſſue.

After this, I took a ſmall Frog, whoſe body was about an inch and an half in length, which I put into a glaſs tube together with a large Spider, in order to ſee the actions of theſe two animals when brought together; and I obſerved the Spider paſs over the Frog without hurting it, though with its fangs diſplayed as if to attack the Frog. Upon this, I cauſed the Frog to fall againſt the Spider, who, thereupon, ſtruck his fangs into the Frog's back, making two wounds, one of which exhibited a red mark, and the other a purple ſpot. I then brought the Frog to the Spider a ſecond time, who, thereupon, ſtruck his fangs into one of the Frog's fore feet, whereby ſome few of the blood veſſels were wounded. And having provoked the Spider a third time, he ſtruck both fangs into the Frog's noſe,

preſently after which, I took the Spider out of the glaſs. The Frog, thus wounded, ſat without motion, and in about the ſpace of half an hour, it ſtretched out its hind legs and expired.

The next day I brought another Frog, about the ſame ſize as the former, to the ſame Spider, but though it was twice wounded, I did not perceive it to be injured thereby, perhaps becauſe the Spider's bite may not be ſo venomous in our climate as in warmer regions, or elſe, that the poiſon of this Spider might have been exhauſted by former attacks; the Frog I threw back into the water whence I had taken it.

Towards the end of October, I took ſeveral of the largeſt Spiders that could be got, and placed them in glaſſes apart by themſelves, in order to wait for their laying eggs, which I purpoſed to open, and examine the contents. Two of theſe Spiders, after being confined ten or twelve days, I found had laid their eggs, and enveloped them in ſo thick a web, that I was aſtoniſhed to behold it, conſidering that it had been ſpun in a few hours ſpace.

Some of theſe eggs I opened, and found the inſides to be of a yellowiſh colour; the form of each egg was almoſt round, and nearly the thirtieth part of an inch in diameter, and the whole collection of eggs laid by one Spider compoſed a rounding figure, almoſt ſpherical, nearly half an inch in diameter, from whence may be computed how great a number of eggs the Spider lays. And one would almoſt think it impoſſible for ſo many to be contained within this creature's body; ſince upon viewing them with the naked eye, as they lie together in regular order, they occupy a larger ſpace than the ſize of the animal itſelf. But it muſt be conſidered, and it is what I have often experienced in opening Spiders, that the eggs while within their bodies are not of a globular figure, but being very ſoft they lie compreſſed together, and therefore are of divers ſhapes, but as ſoon as emitted from the Spider they aſſume a ſpherical form, by

reaſon of the equal preſſure of the atmoſphere on every part of them; and when of this round figure, being placed in exact order, ſide by ſide, and only touching each other in a point, they muſt neceſſarily, to our view, occupy more ſpace that they did while in the animal's body.

I at firſt was not able to conceive by what means the Spider could place its eggs ſo exactly in the centre of the web, but now I was ſatisfied in that particular, for while I was obſerving a third Spider which was fixing a web to the glaſs in order to lay her eggs in it, I ſaw that firſt ſhe made a kind of thick layer of threads, and faſtened them to the glaſs before ſhe began to lay one egg; and it was moſt worthy of remark that this layer or ſtratum was not flat, but curiouſly made with a roundiſh cavity. In about three quarters of an hour's ſpace, upon again obſerving the Spider, I ſaw that this cavity was not only filled with eggs, but that eggs were piled up above the edges of it to the ſame heighth as the hollow of the cavity below, and the Spider was then buſied in ſpinning a web to encloſe the eggs on every ſide. For this purpoſe ſhe employed not only the hind part of her body from whence the threads were ſpun, but her two hinder feet, with which ſhe placed the threads in due order. And now all the organs uſed in producing the threads appeared in view, each of them in the act of emitting its particular thread. I alſo obſerved the Spider elevate the hind part of its body about the breadth of a ſtraw, and then fix the thread which by the elevation had been drawn out to that length, to the web which was already ſpun about the eggs.

I was very deſirous to ſee a Spider in the act of laying its eggs, which at length I obtained a ſight of, and obſerved that they were not emitted from the ſame part as is uſual in all other minute animals; but from the fore part of its belly, not far from the hind legs, and near the place, I obſerved a kind of little hooked organ, handſomely ſhaped, which I had often before ſeen in this animal, and

could not imagine for what purpoſe it was deſigned ; but now I perceived, that it extended over that part whence the eggs iſſued, and I therefore conjectured that its uſe was to depoſit them in regular order within the web prepared to receive them. To give ſome repreſentation of theſe parts, I cauſed a drawing to be made of a middling ſized Spider, lying flat on its back, with the legs contracted, as if it were dead. This is ſhewn in *fig.* 23, ABC, and near to letter D is the hook juſt mentioned.

This hook I then ſeparated from the Spider's body, and placing it before the microſcope I delivered it to the limner, that he might make a drawing of it as it appeared to him. This drawing is given at *fig.* 24, GHIK, and therein between the letters I and K, certain folds or wrinkles appear, this organ being ſo formed as to have a greater extent of motion and action than uſual. The letters EF denote that part which was joined to the Spider's body.

On the firſt of January, I put ſome Spider's eggs into a glaſs tube which I conſtantly carried about me, in order to diſcover whether by the warmth I imparted to them, they would be hatched ſooner than the uſual time, which is in the ſpring ; and on the 17th of January I ſaw above twenty five young Spiders compleatly hatched, and as many more half way out of the eggs ; and in the evening of the ſame day I counted above an hundred and fifty young ones. The next day, the number was not increaſed, for the remainder of the eggs, to the number of fifty, or thereabouts, were either barren, or the young Spiders were dead within them.

Upon expoſing the glaſs tube at this cold ſeaſon, to the air for about a quarter of an hour, the young Spiders lay without motion, but upon applying ſome warmth to it, they began to move, and the greater number of them crouded themſelves together in an heap, after the manner of bees, within the web where the eggs had been. On the 21ſt of January I could diſcern eight eyes in each of them,

which till then had not been viſible, and on the 25th of January they began to ſpin webs in the ſame manner as full grown ſpiders.

I had hitherto been at a loſs to conceive how this great number of young Spiders could be ſupplied with nouriſhment, conſidering that the natural food of this creature is the ſubſtance of other inſects; but I now perceived that they had fed on the barren eggs which had been left in the glaſs, and they afterwards devoured one another till they were reduced to a very few in number.

I have often compared the ſize of the thread ſpun by full grown Spiders with a hair of my beard. For this purpoſe I placed the thickeſt part of the hair before the microſcope, and from the moſt accurate judgment I could form, more than an hundred of ſuch threads placed ſide by ſide could not equal the diameter of one ſuch hair. If then we ſuppoſe ſuch an hair to be of a round form, it follows that ten thouſand of the threads ſpun by the full grown Spiders when taken together, will not be equal in ſubſtance to the ſize of a ſingle hair.*

To this if we add that four† hundred young Spiders at the time

* This is found by multiplying the number of Spiders' threads, conſtituting the diameter of the hair (which the Author computes to be one hundred) into itſelf, the contents of cylinders (which round threads may be called), being in the ſame proportion as the ſquares of their diameters—

therefore	100	diameters of the thread
multiplied by the ſame number	100	
the ſquare will be	10,000	the proportionate ſize of the hair,
and this being multiplied by	400	the ſuppoſed bulk of a young Spider com-
	4,000,000	

pared with an old one, gives four millions, the proportion aſſigned by the Author to the young Spiders' threads.

The Author's manner of computing theſe very minute dimenſions, is fully explained in the Introduction.

† The difference in the ſize of garden Spiders in Spring and Autumn, muſt have been noticed by almoſt every one, and the Author in his computation, conſiders them as ſpheri-

when they begin to ſpin their webs, are not larger than a full grown one, and that each of theſe minute Spiders poſſeſſes the ſame organs as the larger ones, it follows, that the exceeding ſmall threads ſpun by theſe little creatures, muſt be ſtill four hundred times ſlenderer, and conſequently that four millions of theſe minute Spiders' threads cannot equal in ſubſtance the ſize of a ſingle hair. And if we farther conſider of how many filaments or parts each of theſe threads conſiſts, to compoſe the ſize we have been computing, we are compelled to cry out, O what incredible minuteneſs is here! and how little do we know of the works of Nature!

I never could procure a ſight of theſe animals when coupling together, either in the gardens or fields, nor when incloſed in glaſſes, for I always perceived the female to run away at the approach of the male, and having at one time incloſed three male Spiders with a female in one glaſs, the female flew at the males with ſo much fury, and wounded them to ſuch a degree, that blood iſſued from their legs and feet. Hereupon I killed the female, and the next day I ſaw two of the males lie dead, and the ſurvivor employed in devouring the dead female.

Theſe are the chief of my obſervations on the Spider, an animal held in ſuch deteſtation by many, that they dread even the ſight or approach of it, but in which we find as much perfection and beauty as in any other animal.

cal bodies, which according to the rules of arithmetic, are in the ſame proportion to each other as the cubes of their reſpective diameters. Thus, if a young Spider's body is a ſeventh part of the diameter of a full grown one, the latter will be 343 times the bulk of the former, if an eighth part, 512 times. The proportion here aſſigned by the author, is nearly the medium between theſe two.

OF THE SILK WORM.

THE Royal Society having recommended to my examination, the fruitful and barren eggs of the Silk-worm, I procured a number of thoſe eggs, which had been lately laid by the Moth or Butterfly produced from that inſect; this was about the beginning of the month of September. Theſe eggs, when firſt laid, were of a yellowiſh colour, which in about two days time aſſumed a reddiſh caſt, and at ſix days end they appeared to the naked eye of a liver colour. ſeveral of them I opened, by taking off the upper part of the ſhell with as light a touch as poſſible, and in every one of them I obſerved an exceeding ſmall and delicate membrane, which to the naked eye appeared blackiſh, but on examining it by the microſcope, I found the real colour to be violet, but where the violet particles compoſing it lay cloſe together, they aſſumed a blackiſh appearance. This membrane lay next to the ſhell of the egg, and I imagined, that within it the future Silk-worm would be formed; and in the part where this membrane was joined to the ſhell, I ſaw a minute ſpeck or ſpot, which I concluded to be the vital principle, and the rather, as this ſpeck was wanting in thoſe eggs which I found to be afterwards barren; and it is further to be noted, that in the barren eggs no ſuch membrane as I have mentioned was formed, nor did they change their original yellow colour. This membrane in a ſhort time extended over the whole inſide of the egg, and being ſeen through the ſhell, which is tranſparent, cauſed it to appear of a bluiſh colour.

Some of theſe eggs, which were ſix weeks old, I put into a flat

ſcrewed box, which in the day time I carried in my pocket, and at night placed beſide me in bed, that they might continually be kept warm ; and in another box of the ſame kind, I put ſome more eggs, three weeks old, and theſe my wife (who was always very warmly clad) conſtantly carried in her boſom. This we did, to try the experiment, whether it were poſſible to promote the growth of Silk-worms in the autumn.

In the month of October I opened ſome of the eggs which I had thus kept by me for about a month, and in one of them, I obſerved a minute Silk-worm, about the thickneſs of an hair, and proportionable in length, but I was not able to diſtinguiſh any particular parts in its body. In the ſpace of ten days more, I found larger worms in the eggs, whereupon, I opened ſome of thoſe which my wife had carried about her, and in thoſe, I ſaw Silk-worms, which by the microſcope, appeared as large as one's finger, and theſe I propoſed to have given drawings of, but the animals ſoon drying, and all the moiſture in the eggs evaporating, they entirely loſt their figure, ſo that neither the head nor tail, nor any other parts of their bodies could be diſtinguiſhed, although I had very plainly ſeen them when the eggs were firſt opened.

After this, I from time to time opened others of theſe eggs, but I could not perceive any farther growth in the animals, and at length all the moiſture in the eggs ſo dried away, that they loſt their ſhape and became flattened.

In the beginning of May, in the following year, I opened ſeveral of the eggs which had remained all the winter in my ſtudy, and then I obſerved minute Silk-worms within them, and a kind of globular particles lying cloſe to them, which I judged would afterwards be formed into the limbs of the animals.

Towards the end of this month, the Silk-worms increaſed in growth very rapidly, ſo that on the 20th of May, upon opening ſeveral of the eggs, I could perceive, not only ſeveral parts of each

animal's head, but alſo a great number of ſmall veſſels in it which branched out into others extending all over the body, particularly to thoſe parts where I could perceive the claws begin to appear, and which, therefore, I concluded, were nouriſhed by thoſe veſſels. In ſhort, I ſaw ſuch multitudes of veſſels, with their branches, all of a blackiſh colour, as is not to be conceived, for when theſe branches became beyond meaſure ſlender, they loſt their dark tinge, and at length became inviſible. And I can ſafely ſay, that I do not think I have ſeen ſo many arteries pictured in the drawing of an human body, as appeared in theſe objects, which I ſhould have given a drawing of, but the moiſture in theſe minute veſſels dried ſo quickly, that they loſt their figure, and could no longer be diſtinguiſhed.

On the 21ſt of May, I opened ſeveral more eggs, and ſaw that many of the Silk-worms in the ſpace of the laſt twenty-four hours were ſo much grown, that they appeared compleatly formed, for I could not only ſee the head perfectly formed with all its parts, but alſo all the claws and limbs, and the body every where covered with hairs: upon opening theſe Silk-worms, I ſaw the inteſtines, and now the membrane, which hitherto had incloſed the animal, was diſappeared, the ſubſtance thereof by this time having paſſed into its body, which had aſſumed a blackiſh colour, but the head was particularly black, and I perceived ſome motion in the animal when taken out of the egg.

The next morning, upon opening more eggs, each Silk-worm which had lain in a round poſture within, immediately extended itſelf and crept about, and I found that all the moiſture which I had hitherto obſerved in the eggs was gone, it having paſſed into the body of the worm, which was perfectly dry. In the afternoon of the ſame day, I obſerved that ſeveral worms had crept out of the eggs placed in my cloſet, whereupon I ſat about examining the remainder of thoſe eggs, chuſing ſuch of them, wherein the formation of the ani-

mal appeared to be leaſt advanced, whereas before this I had opened the moſt perfect ones: and theſe I found in the ſame forwardneſs of growth as the eggs I had opened on the 20th of May, and by this time all the dark coloured bodies of the animals, eſpecially the head, might plainly be diſcerned through the tranſparent ſhell.

This rapid formation of the Silk-worm, and its motion within the egg, excited in me the greateſt admiration, and if I had not proſecuted the obſervations I have been relating, I ſhould have thought it abſolutely impoſſible: for, in the preceding autumn, I had placed theſe eggs in a much greater degree of heat than they were now expoſed to, and yet I could not at that time promote the perfect formation of the animals within them. And, from my preſent obſervations, I was led to conclude that it has been an eſſential property of this creature, implanted in its ſpecies at the firſt creation, that the vital principle muſt lie ſhut up in the egg for more than the ſpace of ſix months, without any augmentation of its ſubſtance, except in the formation of that part which is to ſerve firſt for the defence and preſervation, and afterwards for the nouriſhment and increaſe of the animal, and this is the membrane or ſkin I have before deſcribed; and that were it not for this proviſion made by nature, the whole ſpecies of the Silk-worm would be liable to periſh in one year: for if a warm ſeaſon in autumn ſhould cauſe the worms to be excluded from the eggs, the ſucceeding cold and rains muſt prove their deſtruction.

I obſerved that the Silk-worms always came forth from their eggs in the morning, and not in the afternoon. To aſcertain this, on the laſt day of May, in the evening, I counted the eggs I had then left, which I found to be about two hundred. The next day, namely, on the firſt of June, at ſix in the morning, ninety-ſeven Silk-worms had come out of their eggs, and the ſame day at dinner-time, or about one o'clock, thirty-two more. In all the afternoon, although the atmoſphere was warm, only one made its appearance; but the next

day, at ſeven in the morning, forty more were excluded from their eggs.

I always found, that the opening in the ſhells, through which the worms crept forth, was blackiſh about the edges, and, as I could not conceive this blackneſs to be cauſed merely by the touch of their bodies as they crept through the opening, I carefully obſerved the animals at the time they were employed in biting or gnawing open the egg, and I always perceived, that in doing this, they frequently emitted a blackiſh watery humour or liquid from their mouths, with which they moiſtened the ſhell in that part where they were biting it, and this not merely on the inſide, for when they had made the aperture large enough for them to emit this liquor on the outſide, they then moiſtened the ſhell both within and without. I alſo obſerved, that when the worm was about moiſtening the ſhell, it ceaſed biting or gnawing for a ſhort time, until (as I ſuppoſe) it had brought into its mouth a portion of the liquid for that purpoſe, in like manner as oxen, while chewing the cud, deſiſt at intervals for a ſhort ſpace, until they have produced a freſh portion of their food from their ſtomachs.

From hence I concluded that without this kind of liquid, it would be impoſſible for the young Silk-worm to open to itſelf a paſſage through the ſhell of the egg. And I ſaw that the animal was very ſparing in the conſumption of this liquid; for in that part where it had moiſtened the ſhell, it continued to bite or gnaw (without moving to a freſh place), until (as it appeared to me) it had eaten or taken into its mouth the liquid, and the bitten or ſcraped-off part of the ſhell. At which inconceivable perfection in this little creature, I was ſtruck with aſtoniſhment, and I drew from it this concluſion in my mind, that not only the Silk-worm, but other creeping inſects, when come to maturity in their eggs, do emit ſome liquid matter from their bodies, in order to ſoften the ſhell in that part where they are endeavouring to break forth, and poſſibly this liquor may have in

it ſome acute or corroſive ſalt, fitted for ſoftening the ſhell of the egg.

I cannot quit this part of the ſubject, without exhibiting the formation of the Silk-worm's egg, becauſe the ſeveral particles of which it conſiſts, are ſo firmly and cloſely united together, that they preſerve the liquid ſubſtance within the egg many months without the leaſt evaporation.

Plate II. *fig.* 25, F G H, is the ſhell of the Silk-worm's egg, opened by the animal, as it appeared to the limner through the microſcope; G H, is part of the aperture which the worm, by biting or gnawing, opened for itſelf, and through which it crept out of the ſhell.

Some years after the preceding obſervations, I further proſecuted my enquiries by obſerving the Silk-worms as they advanced in growth, which I could eaſily do, having two mulberry trees in my garden, which ſupplied me with food for the worms, of which I had three or four hundred.

I have often by the microſcope examined the cuticle or thin ſkin which is ſhed by theſe inſects the * laſt time before they are full grown, and particularly the more ſolid part of it which covers the head; and with great wonder, I beheld in it all the organs or members with which the head is furniſhed, and particularly I ſaw a number of eyes diſpoſed on each ſize of the head, in fit order to enable the animal to ſee every object around it: further to examine which, I have ſeveral times cut off the heads of full grown Silk-worms, for otherwiſe they were in ſuch continual motion, that I could not clearly diſtinguiſh theſe eyes. When the Silk-worms were changed into aurelias, I ſaw the ſkins of their heads and the reſt of their bodies, which they had put off on the change, and upon examining theſe by the microſcope, I always found the horny coats of the eyes in their caſt-off ſkins. Several parts or pieces of the head with the eyes in

* Silk-worms ſhed their ſkins four ſeveral times, before they begin to ſpin their cone or covering.

them, I placed before the microſcope, and delivered them to the limner, that he might make a drawing of one of them.

Fig. 26, QRSTVW, repreſents one ſide of the Silk-worm's head, with ſix eyes placed therein; on view of which, it plainly appears that the eye marked with the letter Q, is deſigned to view objects directly in front; that marked R, to look a little obliquely forwards, and at the ſame time upwards; the eye marked S, to look on one ſide, and at the ſame time a little upwards; that marked T, to look rather backwards, and alſo obliquely upwards; the eye marked V, to look entirely backwards; and that marked W, downwards. And, conſidering that the eyes of theſe creatures are immoveable, the number and poſition of them as before deſcribed (ſix on each ſide), are the beſt calculated for enabling the animal to ſee all circumjacent objects.

At the ſame time, I obſerved the teeth or pincers with which the head is provided, and with which this animal bites or chews the leaves it feeds on; a row or ſet of theſe teeth is placed on each ſide of the head, and they moſt exactly fit into or correſpond with each other. *Fig.* 27, ABCDE, repreſents thoſe teeth which were placed on the right ſide of the head, and here may plainly be ſeen how each tooth has a thickneſs or riſing about the middle of it, in order to give it ſtrength, whereas the parts of the teeth between D E, are exceedingly ſharp and fine, in order more effectually to cut or chew the leaves: and each of theſe teeth has the ſame thickneſs or riſing, both on the inſide and outſide. The part repreſented at ABCD, appears very thick in proportion to its ſize, but upon more narrowly examining it, I found that this thickneſs did not conſiſt of a ſolid bone, but was hollow within, which cavity probably had been filled by ſome kind of muſcle. At A and B, appear two round boney parts, which in my opinion fit into hollow ſockets in the head, ſo as to give the teeth free and ſufficient motion.

When I firſt examined the Silk-worm's thread by the microſcope, it ſeemed to me not to be of a round form but flat, for the ſame thread appeared in ſome places four times thicker or broader than in others; I alſo thought, that each of the threads was double, or compoſed of two others, foraſmuch as the middle of the thread always ſeemed darker than the reſt, and the whole appeared, as if one were to ſuppoſe, two tranſparent threads lying cloſe and parallel to each other, and glued or faſtened together, and each of theſe two threads not to be ſo pellucid at the ſides as in the middle.

I next conſidered with myſelf, whether theſe ſingle threads might not be compoſed of many ſmaller ones, and having at length found means to break or ſeparate them into very ſmall fragments, I plainly perceived each of them to be compoſed of a number of exceſſively minute filaments.

Farther, I placed a Silk-worm which was beginning to ſpin its ball or covering, in a glaſs tube, large enough to give the animal liberty to move and turn itſelf about, and I obſerved it to fix the thread in various places, ſometimes to the glaſs and afterwards to the threads already ſpun, by means of a certain glutinous or gummy matter, with which the threads are ſmeared when they firſt iſſue from the animal's body. In the progreſs of its ſpinning or forming its ball or cone, the Silk-worm frequently changed its poſition, and carried the thread by various turnings and windings in every direction, it being implanted in this creature by nature, always to form its cone or web of an equal ſubſtance and ſtrength in every part next its body.

Upon examining this cone or ball of ſilk by the microſcope, I perceived in hundreds of places, that the threads of which it was compoſed, were not ſingle but double threads, and this was more particularly diſtinguiſhable in thoſe places where they were bent in a very ſhort elbow or turning in their fixure, either to the glaſs or to one another. This is explained at *fig.* 28, A B C D, which repreſents

a very ſmall particle of the Silk-worm's thread, and this is here ſeen to be formed of two others, which, for the greateſt part, are joined together as at letter A, but where there is a ſhort turning or winding they are ſeparated, and appear in two parts. This double thread remains united, by means of the viſcous or gummy matter before mentioned, until, by being immerged in water, the gum is diſſolved.

Now, if we conſider that the Silk-worm's threads are not round but flat, we ſhall preſently diſcover the reaſon why no ſubſtance, whether of wool or hemp, how fine ſoever it may be, can be formed into cloths or ſtuffs, that will compare with ſilken garments in the gloſſineſs of their appearance. For, the flat ſurfaces of the ſilken threads, reflect the light more copiouſly and ſtrongly, producing their glittering or gloſſy appearance, whereas the light which ſhines on ſmall round bodies is very little reflected from them.

In order to exhibit the flatneſs of theſe double threads more plainly to the limner, I twiſted ſome of them a little, and then placing them before the microſcope, I cauſed him to make a drawing thereof. One of theſe threads is ſhewn at *fig.* 29, EFGHI, and between the letters FG and HI, it is pictured as ſeen obliquely, proving that the threads as ſpun by the worm are not round but flat; they are likewiſe ſo tranſparent, that one thread can eaſily be ſeen through another which is placed upon or over it.

Let us but attentively conſider the make and compoſition of ſuch a thread as the Silk-worm's, bearing in mind alſo, how wonderful muſt be the ſtructure of the creature's body from which theſe double threads are produced, each of which again conſiſts of a great number of oblong particles or ſmaller filaments; and when we further reflect that from ſo moiſt and watery a body as is the Silk-worm's, ſuch ſtrong and tough threads are produced, capable of being applied to the many purpoſes we continually experience, who, upon ſeeing all

this, can refrain from exclaiming with me "How inſcrutable and incomprehenſible are the hidden works of Nature!"

The ſilken caſe or web of which I am now treating, and which the induſtry and ingenuity of mankind has converted to ſo many uſeful purpoſes, is conſtructed by the animal for no other end than that, when its change into a chryſalis or aurelia approaches, and it cannot then be concealed under the leaves of the trees, nor can during the time of its change adhere to any thing, nor even change its place, and during all that time lies as it were motionleſs, it may be preſerved from becoming a prey to birds; and this I am well convinced is the caſe with all inſects of the caterpillar kind, which, when they are full grown, and their change approaches, wrap themſelves in ſome kind of web or covering.

But my chief object, in all theſe my obſervations, was, to diſcover as much as poſſible the nature of that organ from which theſe two threads proceed, and by what contrivance they are joined ſo cloſely together: the common opinion reſpecting which threads is, that they iſſue from the animal's mouth. For this purpoſe I found it neceſſary to fix a Silk-worm on its back, and then the organ, which is placed below the mouth, appeared in ſight. *Fig.* 30, A B C, exhibits this organ. The parts marked D E and F G are placed below the mouth, and the organ from which the threads iſſue is ſituated ſtill lower. While the limner was making this drawing, ſome part of the teeth appeared in his view, which he alſo included in the figure, at the letters H I K, and this was done, more clearly to prove, that the threads do not proceed out of the Silk-worm's mouth, as is the vulgar opinion.

After I had diſcovered the particulars above enumerated, I endeavoured to inveſtigate the matter or ſubſtance from which the threads are formed in the body of this inſect. For this purpoſe I cut off the heads of ſeveral Silk-worms which had begun to ſpin their web or cone, and then I ſaw, beſides the other internal parts, two oblong

and round bodies four times folded or doubled together, which I took out of the animal's body. Theſe parts were almoſt twice the length of the Silk-worm, and at one end, the ſituation of which I conceived was in the head, they terminated in a point, and ſometimes I ſaw iſſue from this pointed end, an exceſſively ſlender thread, four times the length of the Silk-worm.

Theſe organs, or rather veſſels, in the thickeſt parts of them, were of a red colour, yet when examined by the microſcope they ſeemed yellow; but when I ſeparated the inner from the external part of them, the exterior part ſeen by the naked eye appeared of a perfect yellow.

Fig. 31, LMN, ſhews one of theſe bodies or parts which I have been juſt deſcribing, and of the ſame ſize it appeared to the naked eye when dry and contracted. The letters M and N denote how far the red colour extended; from L to M was of a perfect yellow, and here I judged that the thread when produced from the interior part of the animal's body was kept ready for uſe. At N is the ſmall end, the ſituation of which was near the head, and indeed within the head itſelf. Between L and O, in my judgment, is the way or paſſage through which is conveyed the matter or ſubſtance of which the threads are compoſed. This part was of a yellow colour, and is longer than here pictured, being broken off at O. Another part or organ of the ſame make and ſhape, was alſo contained in the Silk-worm's body, and from theſe two parts the ſubſtance is ſupplied for producing the two diſtinct threads I have been deſcribing.

Sometimes when this part or organ was broken off at N, I perceived in it a kind of cavity, but extremely minute.

I oftentimes took hold of the end of the thread which the Silk-worm was preparing to ſpin, and drew it out from the body with ſo much rapidity, as by twenty-five times to exceed the ſwifteſt motion of the worm in its own ſpinning; and I found that when the thread was drawn forth to the length of about fifteen or ſixteen inches, it broke

marked
Silk-worm
threads were
distance than
distance

with a proportionable quantity of the glutinous or gummy matter before-mentioned. In ſhort, there is no doubt that the ſame perfections exiſt in a newly-hatched Silk-worm, as can be diſcovered in one full grown.

I have frequently examined the flying inſect, moth or butterfly produced from the aurelia or chryſalis of the Silk-worm; and, having before particularly deſcribed the eyes of this creature while a worm, I now employed myſelf to diſcover the nature of its eyes, when changed into a moth; and for this purpoſe I placed before the microſcope one of thoſe organs of ſight, which in this animal is commonly deemed one eye. This is protuberant or riſing above the head, rather more than an hemiſphere, and is compoſed of a number of ſmaller optical organs: Theſe I counted with the greateſt exactneſs I was able, beginning at the bottom of the hemiſphere, and proceeding to the ſummit or uppermoſt part of it, which diſtance made the fourth part of a ſphere; and in this ſpace I counted thirty-ſix optical organs or eyes. But, not ſatisfied with my own computation, I delivered the microſcope to the limner, deſiring him to count them, and in the ſame ſpace he reckoned thirty-five. This latter number I will ſuppoſe to be right, and from it I proceed to compute as follows: —If the fourth part of the circumference or great circle ſurrounding a ſphere contains thirty-five, the entire circumference will contain 140. Now Metius informs us, that having the length of the great circle in a ſphere, the calculation of the whole ſuperficies of ſuch ſphere is beſt and eaſieſt computed, thus: As 22 is to 7, ſo is the quadrature of the great circle to the ſuperfices of the ſphere, therefore in the preſent caſe the computation is as follows;—

As 22——7——19600

7

22)137,200(6236

8

140 the circumference or length of the great circle.

140

5600

140

19600 the quadrature of the great circle.

From hence it follows, that each of the ſmall parts or organs of ſight of this inſect, which is vulgarly deemed but one ſingle eye, is compoſed of more than three thouſand optical organs or eyes, but if both parts together conſtitute a ſphere, they then contain 6236 optical organs or eyes.

I have cauſed this part or eye of the inſect to be drawn of the ſame ſize as it appeared to the naked eye of the limner, to give the better idea of the wonders which are concealed in ſo ſmall an animal. This is ſhewn at *fig.* 33, between the letters L and M. Each of the optical organs contained in this eye is ſeparated from the reſt by a line or diviſion of ſix ſides, or of an hexagonal figure, and all theſe hexagonal organs or eyes are placed in the moſt exact order that can poſſible be conceived. A few of them, as ſeen by the microſcope, are ſeen at *fig.* 33, *a*, *b*, *c*, *d*.

When this little part, cleared from the optic nerves within it, was place before the microſcope, all the ſurrounding objects were clearly to be ſeen through each of the ſmall optical organs I have been deſcribing, though wonderfully diminutive; for the great tower or ſteeple of our new church in Delft, which is three hundred feet high, and about ſeven hundred and fifty feet diſtant from my houſe, when viewed through any one of theſe optical organs, appeared no larger than the point of a ſmall needle ſeen by the naked eye: and from hence may eaſily be collected how minute the optic nerves muſt appear to me.

Now, if we conſider that a Silk-worm, within the ſpace of eight or nine days, ſhall not only have ſpun its web, cone, or ball, but alſo ſhall be changed into an aurelia or chryſalis, and that in the ſame ſpace of time, not only its eyes but all the members pertaining to it as a flying inſect ſhall be formed, who can avoid being ſtruck with amazement at all theſe wonders in one Silk-worm? And yet, how little do we diſcover in compariſon of thoſe things which now are and for ever will be hidden from our ſight? the whole of which I

am fully perſuaded no one will ever be able to dive into, and to explain their cauſes and effects.

If we examine the wings of this creature by the microſcope, we ſhall find them covered with an incredible number of feathers, of of ſuch various forms, that if an hundred or more of them were to be ſeen lying together, each would appear of a different ſhape. To ſhew more clearly this wonderful object, I cauſed eight different feathers to be delineated, for I do not remember that I ever ſaw them of ſo curious a make in any other flying inſect. Theſe feathers are ſhewn at *fig* 34, ABCDEFGHIKLMNO, and the letters ACEG HLN, denote their quills which were fixed in the membrane or ſkin of the wing.

Although the microſcope by which theſe feathers were drawn, repreſented objects very diſtinctly, the limner could not, through it, ſee the ſtreaks or ribs in each feather, until I pointed them out to him. Therefore I put into his hands a microſcope which magnified objects almoſt as much as that by which the Silk-worm's thread was drawn, deſiring him to give the figure of that feather which through it he could ſee the moſt diſtinctly. This is done at *fig.* 35, PQR, in which plainly appear a great number of ſtreaks or parts like ribs, which give ſtrength to the feather, and in ſome of theſe feathers, where they ſpread very wide, as at the part marked R, I have counted as many as thirty of theſe ſtreaks, and if we conſider that every feather is nouriſhed through the quill which is pictured at P, how many and how various muſt be the veſſels in this quill?

After this, I wiped off the feathers from a part of one of the wings, that I might diſcover how cloſe they were placed together, and I found that they were about an hair's breadth aſunder. And if, as a certain writer aſſerts, 640 hairs breadths are equal to one inch, we may demonſtratively conclude, that the four wings of this inſect are covered with more than four hundred thouſand feathers, for the ſur-

face of all the wings when laid ſide by ſide takes up almoſt three quarters of a ſquare inch; and, as each wing is covered on both ſides with feathers, this makes the ſpace of an inch and an half ſquare. To which if we add, that the body and legs of this butterfly are covered with as many feathers as are on the wings, the number of feathers above enumerated will be doubled.

I then examined the boney parts which give ſtrength and ſtiffneſs to theſe wings, and I ſaw more plainly that in other flying inſects the crooked or twiſted veins within them. A very ſmall portion of one of theſe boney parts is ſhewn at *fig.* 36, ABCDEF, within which is ſeen that twiſted vein, and where the bone is divided into two parts, the vein is the ſame. In the ſame figure, at ABH, is repreſented a ſmall part of the membrane or ſkin of the wing ſtripped of its feathers. The dots in it indicate the cavities wherein the quills of the feathers had been fixed.

It is alſo a pleaſant object to behold the curiouſly formed claws in each of the ſhort feet of the Silk-worm, and which are ſhed or put off with the ſkin at the animal's change into an aurelia, one of theſe is ſhewn at *fig.* 37, IKL, and when changed into a flying inſect or butterfly each foot is furniſhed with two nails or claws, with which it very ſtrongly clings to every thing it touches. Theſe nails or claws are ſhewn at *fig.* 38, MNO.

To cloſe this ſubject; ſeeing that the Silk-worm, in its change, only puts off the ſkins of its feet, and that, in the ſame places where, while a worm, it had very ſhort feet; it is, when a butterfly, furniſhed with legs, covered with numbers of feathers, and armed with nails or claws as before deſcribed, the metamorphoſis or change of this creature muſt ſeem almoſt incredible, and cannot but excite in us the greateſt admiration.

On the nature of the ſcales of Fiſhes, and how the age of thoſe Animals may be determined by obſervation of the ſcales; The Author's reaſonings and opinion reſpecting the Longevity of this part of the Animal Creation.

IT is the opinion of the Jews that they are forbidden by their law to uſe the Eel as food, becauſe that Fiſh is ſaid to be without ſcales; and in the book of *Deuteronomy*, Chap. xiv. v. 10. it is written, "whatſoever hath not fins and ſcales, ye may not eat, it is unclean unto you;" and in *Leviticus*, xi. v. 12, are theſe words, (which they apply to the ſame ſpecies of Fiſh,) "whatſoever hath no fins nor "ſcales in the waters, that ſhall be an abomination unto you.

But when I examined this kind of Fiſh, by the microſcope, after I had cleared away that viſcous or ſlimy matter which adheres to them, I found their ſkins to be as completely covered with ſcales as thoſe of any other river Fiſh, which ſcales (though very ſmall and thin) lie as cloſe together and are placed one on another in as regular order as can be obſerved in any other Fiſh whatever, whether of freſh or ſalt water. Moreover, this ſpecies of Fiſh is provided with fins equally as others, namely, one at the head, and one above, and another below, the tail; and becauſe I apprehend that this diſcovery of mine is new, at leaſt to perſons of the Jewiſh nation, (for to this day they deem this delicate Fiſh to be unclean, and hold it as an abomination to them,) I determined to give a figure of one of theſe

ſcales, (taken from the belly of the Fiſh, where they are the ſmalleſt,) as it appeared through the microſcope.

Plate III. *fig.* 1, A B C D, exhibits this ſcale; it was taken from the belly of a large Eel, which, next the head was of the thickneſs of ſeven fingers or thereabouts: on the back and ſides of this Fiſh the ſcales are larger. The greateſt part of this ſcale, A D C was covered by two others. The part B, was placed towards the tail, and in this poſition were all the ſcales; they were all principally compoſed of a kind of globules or little balls, which globules in many places exhibited an appearance, as if they were covered with a cobweb, which by reaſon of its exceſſive fineneſs, could not be expreſſed in the drawing.* In theſe ſcales the globules compoſing them were very tranſparent, though ſome more than others; again, ſome had in them a dark ſpot. Theſe opaque globules lying in rows contiguous to each other, produced the appearance of divers circles or rings on the face of the ſcale. And although I did not obſerve theſe ſcales to be exactly alike, yet the circles or rings ſeemed to me to be of the ſame number in all of them, whence I was led to conclude, that the ſcale had been every year augmented by the addition of one circle, and conſequently, that, as there were ſeven circles in this ſcale, this Eel was probably ſeven years old. Theſe circles are marked in *fig.* 1, by the letters E F G H I K L, and at X the ſcale is repreſented of the ſame ſize as it appeared to the naked eye.

Having examined the ſcales on the body of a very large Eel, I perceived that thoſe on the back and belly of the Fiſh were placed in regular and even courſes behind each other, but that thoſe between the back and the belly were many of them laid obliquely, ſome towards the belly and others towards the back, but all ſo diſpoſed as to cover the ſkin exactly in every part.

* This appearance ſeems to have been afterwards more fully inveſtigated by the Author, and explained by a drawing, as will appear in the following pages.

* After this, I examined the matter or ſubſtance with which theſe ſcales are covered, which, as well as the ſcales, has been generally deemed nothing more than ſlime, and is by moſt perſons thought to be an excrementitious matter, adhering to this ſpecies of Fiſh; but I am now convinced by experience, and the cleareſt ocular demonſtration, that this ſuppoſed ſlime does not collect on the animal's body from without, but is really part of the body itſelf; foraſmuch as this ſubſtance, although it appears to the naked eye, and very often through the microſcope no otherwiſe than like a cryſtalline or pellucid humour or ſubſtance, yet in fact it is no other than a congeries or collection of veins or veſſels, which in their exquiſite fineneſs or ſlenderneſs do almoſt exceed belief, ſpreading themſelves one among another in ſuch an incomprehenſible and immenſe number of branches, that I could not contemplate them without the greateſt admiration. Indeed, many were ſo thin and ſlender, that I could not diſcover them without the moſt careful attention, and I thought it probable that there might be others ſtill more minute, ſo as entirely to eſcape the ſight. Such of theſe veſſels as I could diſtinctly perceive, I judged to be ſo ſmall (meaſuring them by my eye) that if one of the globules† of blood from whence its redneſs proceeds, were to be divided into a thouſand parts, not one of thoſe parts could paſs through theſe wonderfully thin and ſlender veſſels.

From theſe obſervations I concluded, that this ſubſtance only anſwers the purpoſe of a membrane or ſkin lying next to the ſcales, and that, when an Eel is creeping through a narrow paſſage or hole,

* Theſe obſervations of the Author on the Eel appear to have been written poſterior to the time when he publiſhed the preceding ones, and it ſhould ſeem, that what he before deſcribes to be an appearance like a cobweb adhering to the ſcales, is the effect of the veſſels here deſcribed.

† The author's computation of the ſize of a globule of blood, will be found in another place, where he treats of that ſubject.

a part of this membrane or cuticle, which we call ſlime, is rubbed off in the paſſage; and that when Eels are kept in any kind of veſſel without water, and in their motion wear off this cuticle, they cannot long ſurvive; and upon my talking over this ſubject with a Fiſh-monger, who was a very intelligent man in his buſineſs, he confirmed all that I have here mentioned.

Further, I imagined that this cuticle or ſkin ſo covering the ſcales of Eels, and in ſome ſort proceeding from the ſcales themſelves, and the veſſels which in a great meaſure compoſe that ſkin which we imagine to be ſlime, extend ſo far and wide, that the veſſels proceeding from one ſcale ſpread over more than twenty-five others, and that this is the reaſon why this ſlimy matter covering the ſcales is ſo thick and tough.

But, not yet ſatisfied with theſe obſervations, I endeavoured to find out the veſſels in the ſcales from whence theſe ſlimy excrementitious veſſels were formed, and in order to exhibit more plainly the rough or wrinkled make of the ſcales, I have cauſed an exceeding ſmall particle of one to be delineated, the appearance of which, by the microſcope, was that of a lucid or bright cryſtal, both within and without. This is ſhewn in *fig.* 2, I K L M, wherin the ſide I M, repreſents that part which was fixed or rooted in the Fiſh, being about the length of two common grains of ſand. I have ſometimes divided the ſcales of this Fiſh into ſmall parts, and I always found that though the wrinkles in them appeared very pellucid, they were compoſed of nothing but thoſe inconceivably ſlender ſtreaks, or rather veſſels, mixed and twiſted one within another, as is in ſome ſort repreſented in this figure by the letters K L N.

Some years after the preceding obſervations were publiſhed, I received from a perſon of ſome note in this city, a parcel of ſcales taken from a very large Carp which had been kept in his Fiſh-pond, and was ſo tame that it would take food out of a perſon's hand.

But in the time of a ſevere froſt, the gardener being employed in breaking the ice with an hatchet, to give freſh air to the Fiſh in the pond, this Carp came to the hole, and unfortunately received a wound from the hatchet, which occaſioned its death. This Fiſh was in length 42¼ inches, and in circumference at the thickeſt part of its body 33¼ inches.

In order more eaſily to cut one of theſe ſcales in pieces, I ſteeped it in warm water, and then I cut off a ſlice from it, paſſing through that part where the firſt formation of the ſcale appeared, which original ſcale was very minute, and I then obſerved forty rows of ſcales lying one on another, or in other words, this ſingle ſcale was a cluſter of forty other ſcales lying one on another. For every year a new ſcale ſomewhat larger than that immediately preceding it, is added to the number, and is as it were glued to the former ones; therefore as many of theſe ſcales as are found thus joined together, ſo many are the years of the Fiſh's age. This aſſertion of mine is however violently contradicted, becauſe many people think that I cannot by any means prove what I affirm.

I determined therefore, to cut off a ſlice from this ſcale very obliquely, whereby the rows of the component ſcales might be more clearly diſcerned, and I cauſed a drawing of this to be made from the microſcope, which is ſhewn at *fig.* 3, A B C D; the part reaching from A to B, or from D to C denotes the difference in ſize by which each newly-formed ſcale exceeds that of the preceding year, the whole thickneſs of the ſcale as it appeared through the microſcope, is the ſpace between B and C, but in fact, the real thickneſs, as ſeen by the naked eye, is no more than that of an hog's briſtle.

Another piece of the ſame ſcale, cut ſtill more obliquely, I placed before another microſcope, a drawing of which is given at *fig.* 4, E F G H. The ſpace between E and F is the thickneſs of the ſcale, and as many diviſions or rows as are there pictured, ſo many of the

ſmall component ſcales lie heaped one on another, (at leaſt as far as the limner was able to obſerve them) and ſo many years had elapſed between the formation of the firſt ſcale, and all the others which were added to it.

This cutting or ſlicing off pieces from the ſcales, does not ſucceed equally well in all, for ſometimes their thinneſs cauſes it to fail, but if the extremity of each ſcale can but be perceived, the age of the Fiſh may be gathered from it with little danger of miſtake. In order to ſhew this irregular kind of ſection, I cauſed a ſmall piece of that deſcription to be drawn from the microſcope, and this is ſhewn in *fig.* 5, I K L M; here the additional ſcales produced every year, ſometimes appear of a darker ſhade than they are in reality, and therefore the yearly increaſe in ſize ſeems repreſented at I O and M O, but the addition of three years' growth appears at I O K. At *fig.* 6, between P and Q, is ſhewn the natural ſize of the ſlice or piece of ſcale repreſented when magnified, at *fig.* 4.

Since we now find, that the ſcales of Fiſhes are every year augmented in the way I have been deſcribing, we may form a pretty good judgment as to the time when this augmentation is made by analogy to what we obſerve in the other productions of nature, and thence we ſhall conclude that the additional ſcales are compleated at that ſeaſon, when the further growth ceaſes. For this is evident in trees, at leaſt ſuch as grow in theſe regions. The like alſo is the caſe in regard to cows, for between certain ſpaces of time, when their growth is intermitted or ceaſes and when it again returns, it is ſhewn in the horns, whence we gather that as many knots or rings as are found on the cow's horn, ſo many years of age is the animal.

And, though this may not appear exactly in the ſame manner in all creatures, yet we muſt allow, that ſuch a diſtinguiſhing circumſtance exiſts, and this is proved in the falling off of the hair from animals, and the ſhedding of feathers by birds, at certain regular periods.

I have often conſidered with myſelf, reſpecting the longevity of Fiſhes, and I am perſuaded that in deep and extenſive waters, and in running ſtreams, where the water does not corrupt or putrefy, they are not liable to any diſeaſes, nor ever die of old age. Such wounds as a Fiſh may receive, either by ſwallowing the hook baited to catch it, and which, being broken off and remaining in the ſtomach, may cauſe an exulceration; or by devouring ſome ſubſtance which it cannot digeſt, are not to be deemed diſeaſes, but accidents. Now, terreſtrial animals, through great fatigue, heat, cold, hunger or thirſt, may eaſily fall into diſtempers and die, but to thoſe accidents Fiſhes are ſeldom or never ſubject.

Firſt, as to fatigue, this in Fiſhes cannot be great, becauſe their chief exerciſe conſiſts in the larger purſuing the ſmaller, in queſt of them for food; or in the flight of the ſmaller ones from the larger; and in theſe exertions the fine juices of their blood can in no degree, or at leaſt but very little, be exhauſted; becauſe in ſuch kind of purſuit or flight, no evaporation can be produced from their bodies through heat or dryneſs; beſides, they never want for drink, by which means their blood, and the other juices of their bodies are kept continually diluted, ſo that the circulation is conſtantly preſerved.

No one can pretend to ſay that a Fiſh is ever killed by heat, for many kinds of fiſh, in the middle of ſummer, and in the burning heat of the ſun, do either play, as it were, on the ſurface of the water; or hide themſelves under the leaves, weeds, or other ſubſtances at the bottom.

As to cold, we do not know that Fiſh in deep waters ever periſh with cold; but we know by experience, that at ſuch ſeaſons they ſeek the bottom of the water.

As to food, they are not eaſily killed by hunger; many Fiſhes live for five or ſix months ſpace without any other ſupport than what they

receive from the water, or rather from the ſmall particles in it, which are by us commonly conſidered as part of the water only; in ſuch a ſituation indeed, they increaſe little or nothing in ſize, but rather, if they were before fat and plump, they will fall away.

I am alſo perſuaded, that all Fiſhes which have a conſtant ſupply of food, do daily increaſe in ſize, and this without ever ceaſing to grow, ſo that any real definite ſize cannot be aſſigned to them, as it can to terreſtrial animals, ſome of which arrive ſooner, and others later, to their full and perfect ſtature, which they never afterwards exceed, although they continue to live many years. The reaſon of which, I am convinced is this, that terreſtrial animals continue growing as long as their nutritive juices have force ſufficient to protrude or thruſt themſelves through the cavities of the bones, and ſo to increaſe the ſize of them, as well in length as in thickneſs. But when the bones of theſe animals, by being expoſed to the air, are become ſo rigid and hard, that they cannot be any more diſtended, their farther growth muſt neceſſarily ceaſe, and any freſh ſupplies of nutritive juices can only tend to increaſe the animal's fatneſs. But the bones of Fiſhes are for the moſt part deſtitute of marrow, and they cannot be rendered rigid by expoſure to the air, conſequently the very ſmall tubuli or pipes of which they are compoſed, are exceedingly ſoft in compariſon with thoſe of other animals. All which conſidered, there ſeems no reaſon to exiſt, why the bones of Fiſhes ſhould not continue always growing, ſo long as the animals do not want for food.

In the lakes with us, where are many Fiſheries, Pike have been caught of the length of 56 inches, and 36 or 38 pounds weight. Pearch alſo 28 inches long; and who can tell to what ſize theſe Fiſhes might have arrived, if they could have longer eſcaped the nets?

The Author's refutation of the doctrine of equivocal or ſpontaneous generation in the inſtance of the Sea-Muſcle, with a particular deſcription of that ſpecies of Fiſh.

I HAVE been informed, that a book is publiſhed at Rome, by a learned Jeſuit, named Philippo Bonanni, wherein he maintains, that animalcules, or ſmall living creatures, can be produced out of inanimate ſubſtances, ſuch as mud or ſand, by ſpontaneous generation, according to the doctrine of Ariſtotle; and it ſeems that this learned gentleman is himſelf very deſirous to ſee my obſervations on the ſubject. I ſhall therefore proceed to conſider Signor Bonanni's poſitions, and I doubt not, that upon inveſtigation, they will be found of no weight or ſubſtance, but will vaniſh like ſmoke or vapour.

We will admit, that out of the mud or ſand which is found on the ſea-ſhore, or the beds of our rivers, at low water, ſhell-fiſh or teſtaceous animals come forth; but it does not from thence by any means follow, that they are produced without any regular courſe of generation.

Among the mud, in the creeks or ſhallows of our ſea coaſts, are taken great quantities of that ſhell-fiſh, called Muſcles, which are uſed by us as an article of food; and, as I had in the autumn been employing myſelf in obſervations upon this ſpecies of fiſh, I applied to a fiſherman who made it his buſineſs to catch Muſcles, and queſtioned him as to what his opinion was, with regard to the propagation of that fiſh.

This fiſherman, who was a very intelligent man, and of good eſtimation in his profeſſion, and had been brought up to it from his youth, informed me, that he had often experienced, that in the ſame tract of coaſt where he had found for ſeveral years ſucceſſively very good Muſcles, and in great abundance, yet afterwards in or about the ſame place, very few or none were to be got; for which he aſſigned theſe reaſons:

"At the time of the Muſcles laying their eggs or ſpawn, which laſts but for a ſhort ſeaſon, this ſpawn, by ſtrong tides and heavy gales of wind, will be carried from the places where it is depoſited, and when the water becomes ſtill and calm, it will ſink to the bottom, or adhere to the weeds growing there; and then in the ſpace of two or three years, a good and plenteous Muſcle-bank will be formed in the place; adding, that by this means Muſcles are taken where none were ever found before, and Muſcle-banks formed of very great extent, the ſpawn laid by the Muſcles being in ſuch abundance, as to make the ſea-water appear of a white colour."

If then, at the ſeaſon when the Muſcles depoſit their eggs or ſpawn, we take up a quantity of the mud or ſandy matter from the ſhore, and keep it covered with water, we need not wonder if we find Muſcles or other ſhell-fiſh produced from thence; but if we imagine that this comes to paſs by any other means than the ordinary courſe of generation, we ſhall therein deceive ourſelves. And for my part, I hold it equally impoſſible for a ſmall ſhell-fiſh to be produced without generation, as for a whale to have its origin from the mud.

The eggs or ſpawn of Muſcles, and other ſhell-fiſh, being carried along with the ſea-water to the ſides of ſhips lying in harbours, will adhere to them, and become ſhell-fiſh, by which means thoſe ſhips in their voyages to other countries, will introduce ſuch kinds of ſhell-fiſh as were before unknown in thoſe parts.

But how can it be conceived that living creatures can proceed from

ſand, or obtain any nouriſhment from thence? for there is no other difference between the grains of ſand, and the beach-ſtones on the ſea-ſhore, than that the one are larger than the others; and, as incapable as glaſs is of affording ſupport to any living creature, ſo is it impoſſible for any nouriſhment to be found in ſand.

If it were poſſible for the mere ſand on the ſhore to produce ſhell-fiſh, how much would our coaſts abound with them, and not with them only, but alſo with all other ſorts of fiſh; for the flat-fiſh feed on theſe ſmall ſhell-fiſh, and thereby become very fat and good; and ſo does alſo the whiting.

The chief reaſon, in my opinion, why we do not find ſhell-fiſh in equal plenty, at all times, is, that the ſtrong north-weſt winds blowing directly on our coaſt, do ſo ſtir up the ſand and muddy bottom on the ſhore, that the ſhell-fiſh are thereby overwhelmed and buried, and ſo periſh.

During the laſt five or ſix years, we have not had any great ſtorms from that quarter, and we have for theſe laſt three or four years ſucceſſively, had ſuch excellent flat-fiſh, eſpecially flounders, that no one remembers to have ſeen the like; the reaſon for which I have already aſſigned, namely, that the ſhell-fiſh during that ſpace of time, multiplied exceedingly, affording plenty of food for fattening the flat-fiſhes. And this is alſo proved by experience; for whenever flounders are in perfection, their ſtomachs and bowels are found to be full of fragments of ſmall ſhells. And, upon reflecting with myſelf as to the cauſe of theſe ſmall ſhells being ſo broken into fragments, I could not aſſign any other reaſon than the following:

The flounder, ſole, turbot, and other flat-fiſh, are formed by nature with their mouths diſtorted and in a different poſition from that of moſt other fiſhes; and this formation ſeems to be, for enabling them to pick up their food from the bottom of the ſea, and not to go

in chaſe of other fiſh; and I conceive that theſe flat-fiſh, when picking up the ſmall ſhell-fiſh, do break their ſhells to pieces in their mouths (which ſeem to me to be formed principally for that purpoſe) and then ſwallow them, rejecting thoſe ſhells which are too hard for them to break, for which reaſon we never find any very hard or large pieces of ſhells in their ſtomachs; and it is not in the power of the flat fiſh to ſeparate theſe ſmaller ones from their ſhells, becauſe they are all, as far as I have ever obſerved, cloſely united to them by ligaments or tendons, and always keep their ſhells cloſely ſhut.

I have enquired of thoſe Fiſhermen, whom I thought men of reflection, what could be the reaſon why ſome years ago our flounders were very indifferent, and for theſe laſt three or four years ſo exceeding good; for which they could not aſſign to me any reaſon; but when I laid before them my ſentiments reſpecting theſe fiſh being fattened by feeding on the ſmall ſhell-fiſh, they were ſurpriſed thereat, and added, that this might very probably be the caſe. But upon converſing with two principal merchants who ſend out fiſhing-veſſels, they not only agreed with me in my opinion, as before related, but alſo in the following, namely, that not only the flat-fiſh feed ſo much on the ſmall ſhell-fiſh, but the whiting is ſo abundantly nouriſhed by them, that in the ſummer-time its fleſh becomes hard and tough; for this reaſon, at the time when the ſhell-fiſh abound on our ſhores, the whiting reſorts thither in queſt of them, and this latter is followed by the cod-fiſh, which preys on the whiting. In ſhort, I conclude that the plenty of fiſh found on our coaſt, proceeds from this cauſe only, the great quantities of ſhell-fiſh which every year breed there.

Towards the end of the month of February, being the firſt time in the ſpring that Muſcles were brought to our city for ſale, I cauſed ſome of them to be bought, in order to make my obſervations thereon: I found theſe to be very lean, and for a long time my ſearch after their ſpawn was fruitleſs, though I could not think that the time was paſt for their depoſiting it.

Upon examining that part of the Muſcle which is called the beard, I not only found it of a wonderful make, but the motion I ſaw in the ſmall component parts of it was ſo incredibly great, that I could not be ſatisfied with the ſpectacle; and it is not in the mind of man to conceive all the motions which I beheld within the compaſs of a grain of ſand.

When I obſerved the large and ſtrong tendons or ſinews in the Muſcle, which are fixed to the ſhell, and thoſe which lie in the ſame order and poſition as the ribs in a terreſtrial animal, I thought that we cannot ſufficiently admire the wonderful make of this fiſh; and that if we could obtain an inſight into all thoſe parts which we ſee in one of them, and could we aſſign their ſeveral uſes, and give them names, and alſo make drawings of them, I doubt not that we ſhould admire ſo elaborate and curious a work, beyond many others of nature's productions; and that thoſe perſons who now aſſert that ſhell-fiſhes (among which the Muſcle is in leaſt eſtimation) are produced ſpontaneouſly, or of themſelves, would renounce their opinions, and embrace the truth, namely, that ſo perfect a creature cannot be produced from corruption, congealed water, or mud, but can only be generated by parents of its own ſpecies.

I obſerved that every Muſcle was provided with a kind of ſtring or ligament, which, at a little diſtance from the fiſh, was divided into 8, 10, 12, 15, and even 20 other ligaments of different lengths; and with theſe ligaments, I obſerved, that the Muſcles faſtened themſelves to other Muſcles, and alſo to pieces of ſhells, and to ſhell-fiſh of other ſpecies.

I was deſirous to know how this faſtening was effected, and which I immediately diſcovered; for I ſaw, to my great ſurpriſe, that the extremity of every ligament was provided with a thin flat membrane or ſkin, of a roundiſh ſhape, which was as firmly fixed to

the ſhell on which it was placed (the ligament being in the middle of it,) as if it were glued to the ſhell; and when I endeavoured to pull off the ligament, I found, by ſeveral trials, that (though it was very ſtrong and tough, in proportion to its ſize) it would break before the flat thin membrane could be looſened.

Hereupon I recollected, that when a boy, I had often amuſed myſelf with a play-thing which we called * "een Treck-leertje." This is a ſmall round piece of leather, about two inches in diameter, having a ſmall hole in the middle, through which was drawn a pack-thread, with a knot at the end. This leather being firſt ſoaked in water, was placed flat on a ſtone, and with this we could not only lift up the ſtone, but carry it to ſome diſtance.

Now, upon the ſame principle as the ſtone adheres to the leather, partly by the preſſure of the atmoſphere, and partly becauſe no air or water can gain admittance between the ſtone and the leather, the like effect is produced in the coheſion or ſticking of the membrane I have been deſcribing.

I have thought it proper to give a drawing of the ligament beforementioned, and its ſeveral branches: and in Plate III. *fig.* 8, is ſhewn a part of it, which is cut off at A in the part which comes out of the ſhell; this in *fig.* 7, is ſhewn at BE of its natural ſize. In *fig.* 8, FGHIK are ſeen the ramifications or branches, or rather a ſmall part of them; and at LM is ſhewn one of the ſhort ligaments, with its membrane NOP, the ligament here appears on the upper ſide of the membrane, in like manner as if the latter was fixed to ſome other ſhell; and here are to be ſeen the many parts whereby the ligament is joined to the membrane, which latter alſo appears ſomewhat elevated at the place of joining.

* That is, in Engliſh, a pulling or drawing-leather; it is a common play-thing among boys in England, and is called by them a ſucker.

At Q R is repreſented another ligament, and at S T V its membrane, with the concave part of it, appearing open, being in a contrary poſition to the former repreſentation. I have often ſeen this cavity reach into the ligament as far as M or R, but otherwiſe it is quite cloſe and compact.

Each of theſe ligaments conſiſts of a great number of exceſſively ſmall particles, which cannot be contemplated without the greateſt admiration, eſpecially when we recollect the power which the Muſcle has of moving each of theſe ligaments, and alſo that the membrane muſt be placed quite ſmooth and flat upon the ſhell, to which it is fixed, in order to cauſe it firmly to adhere thereto.

Now, if we farther conſider that Muſcles, while in the ſea, always lie with that ſhell upwards which they open occaſionally, and that their ſhells (which are very thin) and their bodies together are but little heavier than the water wherein they live, and alſo that many of them at low ebb-tides are left deſtitute of water, at which times, in my opinion, much air muſt inſinuate itſelf between their ſhells, by which means they become lighter than the water; they would then be liable either with the ebb to be carried out into the deep, or by the flood to be thrown upon the land, and ſo would periſh. But provident Nature has taken care to preſerve them in this reſpect, by furniſhing them with a ligament, ſpreading into various branches, and at the end of each branch an organ, which I have named a membrane, by the help of which the Muſcles can fix themſelves either to empty ſhells, or other ſubſtances, or to one another, by which means they are preſerved.

But as my principal deſign was to diſcover, as far as poſſible, the generation, or procreation, of theſe fiſh, I come now to that part of the ſubject.

I obſerved, that theſe Muſcles, ſome in a greater, and others in a leſs degree, had the outſides of their ſhells covered with a kind of ſubſtance, thinly ſpread upon the ſhell, and firmly adhering to it, or

rather to the membrane which covered it. Obſerving this by the microſcope, I ſaw that the particles of which it conſiſted, were all of a ſimilar form, and alſo placed ſide by ſide, in regular order, and the membranes or ſkins of theſe particles, as it were, united, or cloſely joined together. I ſeparated a part of this ſubſtance from the ſhell and placing it before the microſcope, I found that all the regularly diſpoſed particles were much longer than they were broad, alſo that one of their edges was roundiſh and thick, the other terminating in a point or edge, and moreover that in many of them one ſide was riſing, and the other flat; in a word, many of theſe particles, in ſhape, were very like a Muſcle; and I not only thought that they were the eggs or ſpawn of the Muſcle, but I alſo obſerved, that when I broke the ſtrong membranes incloſing them, ſeveral of the eggs, which were in ſhape like a Muſcle, appeared lying ſingly and ſeparately on the outſide of that membrane; and when I ſeparated theſe unformed Muſcles ſingly, one from another, I imagined that I could ſee the membranes or tendons of which they were compoſed.

I alſo ſaw the ſhells, membranes, or coverings of ſeveral eggs which were empty, and which I ſaw, or more properly ſpeaking, imagined to be barren eggs. In other parts of this ſubſtance I ſaw eggs wherein I concluded that there were unformed Muſcles, which concluſion I gathered from the multitude of veſſels which I ſaw, which veſſels conſtituted the ſhape or figure of a Muſcle.

Theſe eggs were not larger than a grain of common ſcowering-ſand.

Moreover, I obſerved, that the ſmall or taper ends of the ſhells were ſeldom or never covered with the ſpawn or eggs, the reaſon of which I took to be, that at the time the Muſcles emit their ſpawn, they lie with the flat and broad part, as ſhewn at *fig.* 7, A B C D, uppermoſt, and that part marked with the letter A, next the ground, or bottom; for I have often obſerved that when Muſcles have

been cleaned and put into a veſſel of water, and an handful of ſalt thrown upon them, many will be ſoon found placed in the poſition I have mentioned; and while they lie in this poſition, and the eggs are put forth from the part marked C D, there muſt neceſſarily be more eggs lodged near that ſpot, than towards the farther end of the ſhell.

Several of theſe Muſcles I placed in my ſtudy, in two glaſſes of water, with ſome ſalt ſprinkled on them, in order to examine them daily, and ſee the progreſs of growth in the young ones; and upon this occaſion, I could not ſufficiently admire the exact and regular order in which the eggs were in many places diſpoſed, juſt as if they had been ſo placed by men's hands; and from hence I was convinced that Muſcles do not, like many other fiſhes, lay their eggs promiſcuouſly, but that they muſt be furniſhed with ſome kind of organ, which they can project beyond the ſhell, and with it diſpoſe them ſo regularly.

I have before ſaid, that I thought I ſaw a kind of ſinews or tendons in the eggs; and upon further examination, I perceived ſixteen of theſe tendons, like ſtreaks, in the unformed Muſcle, and among them I ſaw ſome ſtill ſmaller ſtreaks, from whence I concluded, that they were in fact, veſſels to form the ſubſtance of the future ſhell, for they lay all in one direction, that is, from the ſmall end, ſpreading or diverging round about; and they were thickeſt at that part, and thinneſt at the extremities, ſpreading wider towards the broad and thin end of the ſhell: I cauſed a drawing to be made of a few of the eggs, in the order they lay on the parent ſhell, and as they appeared through the microſcope; this is ſhewn at *fig.* 9, A B C D E, repreſenting eight of them, in ſome of which it may be ſeen that one ſide is more curved than the other, and in which eggs may alſo be ſeen the ſinews, veſſels, or ſtreaks I have mentioned.

Upon conſidering that the lobſter and the ſhrimp carry their eggs

about them until the young are perfectly formed, it ſeems probable to me, that this is alſo the caſe with the Muſcle, for otherwiſe, how could this ſpecies of fiſh be propagated? eſpecially if we conſider that they lay their eggs in the middle of winter, and are generally in ſhallow waters, where the ſhore is muddy; and if the eggs were not depoſited on the ſhells, they would be buried in the mud, with the common flux and reflux of the tide: not to mention that in ſtormy weather they would be carried out to ſea; but while they are fixed to the ſhells of the parent, and theſe laſt adhering to ſolid ſubſtances on the ſhore, the eggs are, by this means, in great numbers, preſerved; and theſe young Muſcles, when come to ſuch maturity as to be ſeparated from the ſhells, may, in windy weather, ſtrong tides or currents, be eaſily carried to other muddy ſhores on the coaſt, in places where for many years before no Muſcles were to be found.

I have made a rough calculation of the numbers of theſe eggs, and I compute that there are frequently more than two thouſand fixed to the ſhell of one Muſcle; in fact, I have ſeen Muſcles, each of which I judged had more than three thouſand on it.

I have before ſaid, that the eggs of Muſcles are the ſize of common ſcowering-ſand, but as this is not of the ſame ſize in all countries, I compute that, to the beſt of my judgment, ſeven of theſe eggs, in breadth, are equal to the fifteenth part of an inch, conſequently the breadth of 105 eggs, is equal to one inch; and I alſo compute, that ſixty eggs, in length, make an inch; therefore a ſquare inch will contain 6300; and as each egg is no thicker than broad, 105 of them muſt lie one on another to make the thickneſs of an inch; the ſum total then of the eggs which will be contained within the ſpace of a cubic inch, is 661,500; and hundreds of ſuch eggs may lie under ſhells, ſand, or mud, without being perceived, and yet Muſcles be produced from them.

Having taken ſome of the unformed Muſcles out of the eggs, I

cauſed a drawing to be made of their figure, as near as the Engraver was able to imitate it; this is ſhewn at *fig.* 10, F G, which repreſents ſuch an unformed Muſcle, incloſed in its membrane, or covering, in which the ſtreaks before-mentioned, did not appear, until the greateſt part of the moiſture thereof, was evaporated. *Fig.* 11, H I K, ſhews another of them, the ſtreaks, or veſſels in which, between I and K, appeared ſeparated, or ſundered from each other; and this was done in the taking it out of the egg, being in that operation deprived of the ſurrounding membrane, or ſkin.

At the latter end of April, when I had finiſhed the preceding obſervations, I received a large jar full of Muſcles out of Zealand; upon examination of which, I was much ſurpriſed to ſee that moſt of the ſhells were quite ſmooth and poliſhed, being not only deſtitute of eggs, but for the moſt part, bare of the membrane, which gives them a blackiſh colour, ſo that they now appeared of a lively blue; however, I found four or five with perfect eggs on them, and in them were young Muſcles; ſome of theſe I took out of the eggs, and now plainly ſaw, that what I had at firſt taken for the unformed Muſcle, was, in fact, only the ligament, or ſtring, whreby the young Muſcle was nourſhed. A drawing of the real ſhape, as it now appeared to me, is given at *fig.* 12, where G H I repreſents the ligaments of the unformed young Muſcle, and I K the Muſcle itſelf; another of them is repreſented at *fig.* 13, where L M ſhews the ſtrings or ligaments, and M N the Muſcle; and this laſt figure, I think, exhibits the true form of the young Muſcle, as it lies in the egg; and from theſe laſt obſervations it appears, that the parts repreſented in *fig.* 10, at G, and in *fig.* 11, at H, were only the ſubſtance, or matter, from whence the Muſcle would be formed, and which, at the time when that drawing was made, had not come to ſufficient perfection to render the parts diſtinguiſhable.

Now, ſince we ſee, that the eggs of Muſcles adhere ſo long to the

ſhells of the parent, before they are perfectly formed, and alſo conſider that during all that time they muſt be ſupplied with nouriſhment, we ſhall not wonder that the parent Muſcles, during that time, do become lean, eſpecially in the month of April, for then the young are moſt in need of ſuſtenance.

We may alſo here obſerve, that in our enquiries after any truth, and more eſpecially in regard to the generation of ſmall living creatures, which cannot be examined by the naked eye, we ought not to rely on any tales that are told on theſe ſubjects, but on our own experience, and even that not lightly, but by long and unwearied trials and experiments, whereby to come at the truth.

In the courſe of the laſt obſervations, I examined that hard and variegated, or marbly-coloured part, lying in the middle of the Muſcle, which ſome call the heart, and others take to be the tongue of this fiſh; and when, upon the Muſcle, I cut out this part, and placed it before the microſcope, I obſerved ſo tremulous or quivering a motion in the ſurface, as if millions of little living creatures were running about upon it; beſides another motion, which the part had to and fro. This part the Muſcle can extend ſo far, that I think it will almoſt reach all over the ſhell, which made me think that, perhaps, by this organ, the eggs are placed on the ſhell in the regular order I have before deſcribed.

Of the Muſcle which is found in freſh water; a particular deſcription of its internal formation, and of the manner in which its young are produced.

I HAVE obſerved, that when our navigable canals here in Holland, or our ditches are cleaned, a kind of large fiſh are taken from the bottom, named by us, " * Veen Moſſelen," or Peat Muſcles. Of theſe I procured ſome, which were about three or four inches long with very thin ſhells.

A countryman, whom I ſaw collecting theſe ſhell fiſh, told me they were to be found under the banks, and in the ſhallow parts of the ditches, or canals, among the leaves and twigs, or other litter; and, indeed, I have ſeen them taken in thoſe places; but as I was certain that theſe ſhallow places were frozen to the bottom in the winter, which the ſhell fiſh could not ſurvive, I was told that they had a power of moving from place to place.

To ſatisfy myſelf, in this reſpect, I made two experiments on theſe Muſcles, of which I put ſix or eight into an earthen veſſel, with a flat bottom, and poured on them ſome of the ſame water in which they were taken; this veſſel I placed in my ſtudy, and I found that in a few hours time, they had all changed their poſitions, and had approached nearer together, than they were when firſt placed in the veſſel.

* This word, " Veen, " means the Turf or Peat, which is dug up in great quantities in Holland, and is their principal article of fuel. Our author has a very ingenious diſſertation on the origin of this ſubſtance, a tranſlation of which will be found in its place.—Theſe freſh water Muſcles are found in the rivers in England.

And I obſerved, that theſe Muſcles, about the middle of their ſhells, thruſt out, through the opening, a fleſhy ſubſtance, or organ, about two-third parts the length of the ſhell; this part was about half an inch broad, and ſharp at the end; and in order to move themſelves from place to place, they thruſt this organ under their ſhell, and applying it with a quick motion to the bottom of the place where they lay, could by this means not only change their poſture, but turn themſelves upſide down.

At the end of the month of Auguſt, upon opening ſix of theſe Muſcles, I found many eggs within them, which were ſo perfect, that I could diſtinguiſh the newly formed ſhells, ſo that they were not ſo properly to be named eggs as unborn Peat-Muſcles. Two of the parent Muſcles were ſo ſmall, that I judged they were not above a year old, whereas the others were, in my opinion, ſix, eight, or nine years old; but the young Muſcles were of the ſame ſize in all of them.

In the beginning of September, I procured about fifty more of theſe Muſcles, and upon opening twelve of them, I found two wherein the young ones ſeemed to be ſo perfect, that they would probably ſoon be excluded from the parent. I always found that the eggs were firſt formed in the fleſhy part of the Muſcle, but as they advanced in growth, they were moved to that part which, in oyſters, is called the beard, and which, by the great number of the young Muſcles contained therein, then ſwells in bulk.

As there are many perſons who are unacquainted with this ſpecies of Muſcle, and others who may wiſh to inveſtigate the particulars of my obſervations, I have cauſed the following drawings to be made:

Fig. 14. G H I K L, ſhews one of theſe freſh-water, or, as I call them, Peat-Muſcles, of the ordinary ſize, which is opened ſo as to leave the whole of the fiſh lying in one of the ſhells; at H I K, is repreſented the empty ſhell, and at M M, the two tendons, or ſine w by the help of which the fiſh ſhuts and opens the ſhell; and here t.

is to be noted, that theſe fiſhes, by reaſon of the length of their ſhells, are each provided with two of thoſe tendons, or ſinews, whereas oyſters and ſalt-water Muſcles have only one. N O P is a thin membrane, or ſkin, lying folded up, with which the whole inſide of the empty ſhell had been covered, or lined.

Q R S is one of the two receptacles wherein the eggs, as they advance to maturity, are lodged, and which parts do then become ſwollen thereby, but at other times they are very thin; theſe parts, in oyſters, are called the beard; T V is the other of theſe receptacles, which, in oyſters, is alſo called the beard; and in theſe receptacles, I did not obſerve any thing particularly remarkable, except their wonderful make.

W X Y is a ſolid fleſhy part, wrinkled on the outer edge, and in reſpect of the other parts of the fiſh, very ſtrong; this part, as I have already mentioned, the Muſcle protrudes, or thruſts out of its ſhell, to a conſiderable length, when it prepares to change its place; and when at reſt, it generally has a ſmall portion projecting out of the ſhell; but if it be touched, though very lightly it immediately withdraws it. The ſpot marked with the letter Y, is the place where the eggs lie before they are depoſited in what we call the beard; and if an inciſion be made in this part, the eggs, with a watery liquor, iſſue forth.

Some of theſe Muſcles I opened in the preſence of the Engraver, in order, that as ſoon as I had taken ſome of the young ones out of their receptacles, he might make a drawing of them, for, were they ſuffered to ſtand but a few hours, their true figure would be loſt. The unborn Muſcles being put into a glaſs tube, and placed before the microſcope, I ſaw with aſtoniſhment a moſt pleaſing ſpectacle, for every one of them, each in its particular membrane, or covering had a ſlow circumvolution, and that not for a ſhort ſpace of time, but ſuch turning round or rotatory motion was obſervable for three hours afterwards, and it was the more curious, becauſe the young Muſcles, during the whole of their motion, conſtantly kept in the

centre of their membranes, juſt as if one were to ſee a ſphere or globe revolving upon its axis. This uncommonly pleaſing ſpectacle was enjoyed by myſelf, my daughter, and the Engraver for three whole hours, and we thought it one of the moſt delightful that could be exhibited.

Fig, 15. A B C D E exhibits ſix of theſe unborn Muſcles incloſed in their reſpective membranes; they were drawn by the Engraver in the moſt accurate manner he could, while they were in motion. Of theſe, I computed that each parent Muſcle contained ſome thouſands.

I had at the ſame time ſome unborn Oyſters before a microſcope which I had taken out of the parent Oyſter five weeks before, and as they ſtill appeared perfect in ſhape, I cauſed a drawing to be made of them alſo, and this is ſhewn at *fig*. 16, F G H I. In ſome of theſe the openings of their ſhells were plainly to be diſcerned.

Theſe young Oyſters bore the moſt exact reſemblance to full grown ones, though they were ſo minute that one hundred of them laid together would not equal an inch in length, and I have computed that each parent Oyſter contained three or four thouſand of them.

On the Circulation of the Blood; that it is not diſcoverable by the ſight, in an human body, nor in the bodies of terreſtrial animals: the ſame completely ſeen in fiſhes, and the nature of it particularly deſcribed.

THE Blood is compoſed of exceeding ſmall particles, named, globules,* which, in moſt animals, are of a red† colour, ſwimming in a liquor, called, by phyſicians, the ſerum; and by means of theſe globules the motion of the Blood becomes viſible, which otherwiſe would not be diſcoverable by the ſight. Theſe particles, or globules, are ſo minute, that one hundred of them, placed ſide by ſide, would not equal the diameter of a common grain of ſand; conſequently, a grain of ſand is above a million times the ſize of one ſuch globule.

I have often endeavoured to view the circulation of the blood in terreſtrial animals, but without ſucceſs, by reaſon that no parts of their bodies were ſufficiently tranſparent. Among others, I tried the experiment with a young Cock; which I wrapped in a cloth, in order to keep him quiet, leaving out only his head; and inſpected his comb, but could not therein perceive the motion of the Blood:

* Later writers contend, that the particles of Blood are not ſpherical, as this word imports, but plane, or of a flat ſhape; and this Mr. Leeuwenhoek admits to be true with regard to fiſhes. However, the word globules is always uſed to denote the component particles of the circulating fluid.

† In ſome fiſhes the Blood is not of a red colour, and alſo in many inſects, which have been therefore improperly denominated exſangues, or bloodleſs.

I afterwards examined his gills, or thoſe parts hanging under the throat, and there I ſaw it running in an inconceivable number of veſſels; many of which were ſo minute, that numbers of them taken together would not equal the ſize of a ſingle hair: but it was impoſſible for me to trace the circulation in them, by reaſon of their immenſe number, croſſing each other in all directions: for the redneſs which we obſerve in a cock's comb and gills, proceeds entirely from the great number of blood-veſſels on their ſurface, where they are only covered with a thin tranſparent ſkin.

After this, I made my obſervations on white Rabbits, by placing their ears before the microſcope; but, with all my pains, I could not do more than ſee the Blood running with great ſwiftneſs through the arteries and veins. When I plucked off the ſhort hairs from the extremities of the ears, becauſe they obſtructed my ſight, I obſerved, that the pulling off each hair had broken or injured ſeveral of the veſſels, and cauſed an effuſion of blood. From hence I gathered the reaſon, why I had perceived that the pulling out any hairs from the back of my hand produced a redneſs in the part; and I now concluded, that we cannot pull out a ſingle hair from any part of our bodies, while ſuch hair is growing, without injuring ſome veſſels, ſo as to cauſe the Blood to ſtart.

But my greateſt expectation of ſucceſs, was placed on a Bat, becauſe I conceived that the membrane, or ſkin, which ſerves this animal for wings, muſt be ſo thin and tranſparent, as to afford a view of the veſſels. And, having procured one of theſe creatures, I put it into a glaſs and examined it by the microſcope. Here I ſaw the motion of the Blood, both in the arteries and viens, moſt diſtinctly, and fully to my ſatisfaction, though by no means ſo clearly as is to be ſeen in fiſhes; firſt, becauſe the membrane compoſing the bat's wing, is not ſo tranſparent; ſecondly, becauſe there is more of the watery part (or ſerum, as it is called) in the Blood of fiſhes than in terreſtrial

animals; and thirdly, becauſe the particles of blood from which its redneſs proceeds, appear much larger in fiſhes, they being of a flat and oval ſhape; whereas, on the contrary, as far as I could judge from my eye, they, in this animal were ſpherical. I uſed every means I could deviſe to ſee the compleat circulation of the blood, namely, that one of the ſmalleſt of thoſe veſſels which we call veins, aroſe from another which is called an artery, and afterwards conveyed its contents into a larger vein; but this I found to be impoſſible, for when I followed the courſe of the artery, until it became ſo ſmall as only to admit one or two globules to paſs through it at a time, I then loſt ſight of it. If this artery, throughout its circuit, had not been ſmaller than the twenty-fifth part of an hair, I do not doubt that I could have ſeen the whole circulation; but as theſe veſſels were at their extremities diminiſhed to a much leſs ſize, and the membrane of the wing was covered with a kind of ſcales, I could not (as I have before ſaid) follow with my eye thoſe minute ramifications. I perceived, however, in many places, an artery and a vein, placed cloſe beſide each other, and of a ſize large enough to admit the paſſage of ten or twelve globules of blood at the ſame time; and in this artery the blood was protruded or driven forward with great ſwiftneſs, and flowed back through the vein, which was a moſt pleaſing ſpectacle to behold.

I could alſo moſt plainly perceive in the arteries, the riſing, or pulſation, cauſed by the motion which the blood receives from the heart; theſe pulſations were ſo rapid that I judged ſeven ſtrokes were performed in a ſecond of time.

The worm, or ſmall animal which is produced from the ſpawn of frogs, and is called a tapdole, afforded me a ſtill more diſtinct view of this ſubject; for, upon placing one of them, which was newly hatched, before the microſcope, I could diſtinctly perceive the whole circuit of the blood, in its paſſage to the extremities of the veſſels, and in its return towards the heart. But I muſt here obſerve, (as

before mentioned) that if this blood had been an uniformly clear liquor, its motion could not by any means have been diſcovered; but as it conſiſted of a very tranſparent fluid, mixed, as it ſeemed, with globules of different ſizes, which were plainly to be diſtinguiſhed, though they had not, as yet, in this creature acquired any colour, the circulation was thereby rendered very apparent.

When theſe tadpoles were about eight or ten days old, I could perceive a ſmall particle moving within their bodies, which I concluded to be the heart; and the fluid which was protruded from it began to aſſume a red colour.

Upon examining the tail of this creature, a ſight preſented itſelf, more delightful than any that my eyes had ever beheld; for here I diſcovered more than fifty circulations of the blood, in different places, while the animal lay quiet in the water, and I could bring it before the microſcope to my wiſh. For I ſaw, not only that the blood in many places was conveyed through exceedingly minute veſſels, from the middle of the tail towards the edges, but that each of theſe veſſels had a curve, or turning, and carried the blood back towards the middle of the tail, in order to be again conveyed to the heart. Hereby it plainly appeared to me, that the blood-veſſels I now ſaw in this animal, and which bear the names of arteries and veins, are, in fact, one and the ſame, that is to ſay, that they are properly termed arteries ſo long as they convey the blood to the fartheſt extremities of its veſſels, and veins when they bring it back towards the heart. For example, I ſee many blood-veſſels in the tail of a tadpole taking their courſe, as repreſented in Plate IV. *fig.* 1. A B C, where the poſition of the parts A and C is towards the ſpine or middle of the tail, and the part B towards the edge of it. In A B, the blood is driven from the heart, and in B C, it is brought back again, and thus may we ſay, that the veſſel A B C, is both an artery and a vein, for it cannot be denominated an artery, farther than where the

blood is driven in it to its fartheſt extent, that is, from A to B; and we muſt name B C, a vein, becauſe, in it, the blood is returning back to the heart. • And thus it appears, that an artery and a vein are one and the ſame veſſel prolonged or extended.

In the part where I ſaw this circulation, the arteries were no larger than to admit a ſingle particle of blood to paſs freely through them: theſe particles, though in this creature they were of a flat and oval ſhape, yet ſometimes by reaſon of the ſmallneſs of the artery, aſſumed a kind of oblong round figure, and when the animal, by being taken out of the water, grew languid, the blood in theſe very minute arteries began to ſtagnate, and when it again acquired motion, many of the globules appeared twice as long as broad, and alſo pointed at their extremities.

In another place, I ſaw a larger artery divide itſelf into two branches, which are ſhewn at *fig.* 2. D E, and each of theſe branches returned back with a curve, as repreſented at E F and E G. Now, if we denominate D E F, and D E G, arteries, becauſe, in them the blood is driven outwards from the heart, it follows that F H, and G I K, muſt be veins, becauſe they each bring it back towards the heart. Again, not far from K, was another ſmaller artery, which is figured at M L; this was united to the vein I K, ſo that the arteries D E G, and M L, together formed one vein at I K. In a word, in this figure, H F is a vein, D E F and D E G, are arteries; G I K and K I L, are veins, and M L is an artery; and yet we muſt ſay, that theſe are only the ſame veſſels continued.

In another place I ſaw three of the ſmalleſt arteries, after returning in a curve, as before deſcribed, unite in one, and thus form a vein three times the ſize of each artery. But all theſe three veſſels with their bendings wherein the circulation was performed did not occupy more ſpace, than could be covered by a grain of ſand.

I often perceived an artery, taking its courſe over, or croſſing

a vein, and, if a perſon did not clearly ſee the different courſes of the veſſels, he might conclude that here the circulation was performed or compleated, and this I ſaw not only in the ſmalleſt veſſels, but in thoſe which were ten times larger. This tranſverſe courſe, or current of the veſſels, I had often before obſerved in terreſtrial animals, whilſt I was endeavouring to diſcover the conjunction of their arteries and veins. But, as I became then well aſſured, that this conjunction, or circulation, did not take place in the larger veſſels, but in the very ſmalleſt of all, (for otherwiſe I am perſuaded, that all the parts of the body could not be ſupplied with nouriſhment) and that therefore I ſhould in vain attempt to diſcover ſuch circulation, I, ſome years ago, abandoned the farther inveſtigation of it. For, if we now plainly perceive, that the paſſage of the blood from the arteries into the veins of the tadpole, is not performed in any other than thoſe veſſels, which are ſo minute as only to admit the paſſage of a ſingle globule at a time, we may conclude that the ſame is performed in like manner in our own bodies, and in thoſe of other animals. And if ſo, it muſt be impoſſible for us ever to diſcover the paſſage from the arteries into the veins in the human body, or of any terreſtrial ani-animal; firſt, becauſe a ſingle globule, when lying in one of thoſe minute arteries, has not any viſible colour, and ſecondly, becauſe, in thoſe veſſels which are ſo large as to come within our ſight, the blood has not any perceptible motion.

The particles in the blood of frogs are (as before obſerved) of a flat and oval ſhape, and theſe, when viewed ſingly, appear, as I may ſay, colourleſs; but when two are laid on one another, they appear a little of a reddiſh caſt; and where three are together, the redneſs becomes deeper. This may be explained by *fig.* 3. wherein A repreſents one of theſe oval particles, which, in part, is covered by another particle B; and C is a third particle, covering a ſmall part of both A and B; by which means the part at D, where the particles are three-fold, acquires a ſtill darker colour. But when

I have attentively examined one of theſe oval particles on the edge, as is ſeen at E, I have found it exhibit a ſtronger blood-red than where three particles lay flat one on another.

Among the tadpoles, which I cauſed to be taken out of the canals, I perceived a few very ſmall fiſhes, having their ſkins marked with dark ſpots, ſome of which were of the figures of little ſtars. This ſpecies of fiſh I judged to be of its full ſize, becauſe I had never ſeen any by the naked eye of the ſame ſhape as theſe appeared when magnified. One of them I placed before the microſcope, and, upon obſerving the finny part which conſtitutes the extremity of the tail, I plainly ſaw the ſame kind of ſlender arteries and veins as I have before deſcribed, though with more difficulty than in the tadpole, partly, becauſe this fiſh did not long continue quiet, and partly becauſe the particles of Blood (which, in theſe obſervations appeared to me no other than globules) were much ſmaller than in the tadpole. Theſe arteries and veins were placed near the boney parts, or riſings, which give ſtrength to the fin at the tail, and in them I ſaw the compleat circulation of the Blood; for, on both ſides of each of the before-mentioned boney parts was an artery, which had a bending, or backward turning at its extremity, and thus became the beginning of a vein.

Upon viewing this fiſh's tail, at the part where the fin begins, I there ſaw, to my great admiration, a large artery dividing itſelf into the before-mentioned ſmaller ones; and cloſe to it, numbers of the minute veins returning from the fin, and uniting in one large vein. In ſhort, here was ſuch an agitation, or motion of the Blood driven out of the large artery to the fartheſt end of the tail and into the fin, and running back in the ſmall viens, into the large one, as is inconceivable.

In order to ſhew the ſize of this little fiſh, wherein I obſerved all theſe motions of the blood, I cauſed a figure of it to be drawn, as it appeared to the naked eye, and this is ſhewn in Plate IV. *fig.* 4. At

fig. 5, is ſhewn part of the body and the tail of the ſame fiſh, as ſeen through the microſcope. DE is a fin on the back, and L M, another under the belly, near the tail, and FGHIK is the fin of the tail, wherein are to be numbered ſeventeen ſmall bones.

Theſe ſmall bones, contrived by Nature to give ſtrength to the fin, were formed with joints; and I could ſee that they were compoſed of oblong particles, which, probably, were hollow tubes; the pellicle, or membrane, which covered them, and compoſed the greateſt part of the fin, was alſo formed of oblong parts, but theſe things the limner could not perceive, becauſe the fiſh being then dead, they were become inviſible.

I have before ſaid, that on each ſide of theſe boney parts of the tail I had diſtinctly ſeen the compleat circulation of the blood, and this was in thirty-four places, two between each bone; that is, there were in this fiſh's tail ſixty-eight blood veſſels; namely, thirty-four arteries, and as many veins, beſides thoſe veſſels that, probably, were in the ſmalleſt part of the fin, about F or K, which I did not attend to.

To ſhew this circulation more plainly, I cauſed one of the boney parts of the tail to be drawn ſomewhat more magnified, which is repreſented at *fig.* 6, O P Q R. Cloſe to each ſide of this bone lies an artery, which in the figure is pictured at S T and W X, and in theſe veſſels are repreſented the particles of blood, which appear of a round figure. Here the blood was to be ſeen running with a ſwift courſe from S to T, and with the ſame ſwiftneſs returning back from T to V, ſo that S T is an artery, and T V a vein, and yet, both of them but one blood-veſſel, continued and prolonged. In like manner, were the blood-veſſels on the other ſide of the bone at W X Y. But theſe arteries and veins were not at ſo great a proportionate diſtance as here repreſented, for, in many places, they were ſo cloſe as to touch each other.

In other places, and alſo in the two fins D E and L M, I ſaw the blood not only running along, but alſo taking its whole courſe forward and back again, in manner before deſcribed.

Now, if in the tail of ſo ſmall a fiſh, as this which is pictured at *fg.* 4, there are to be found thirty-four diſtinct circulations of blood, what an incredible number of them muſt there be in an human body! And this being ſo, it is no wonder, that, upon the leaſt puncture made by a needle, or any other ſmall inſtrument, the blood iſſues forth. Indeed, from theſe my obſervations, I am well aſſured, that, in the ſpace of a finger's nail, in any part of the ſurface of our bodies, there are more than a thouſand circulations of blood.

Some years after theſe, and other obſervations of the like kind, had been made by me, I accidentally fell into converſation with a certain learned Gentleman, (not a native of Holland) on this ſubject of the circulation of the blood, particularly in the minuteſt veſſels which are contained in a very ſmall ſpace, and that this circulation could as plainly be ſeen, as with the naked eye we ſee water ſpringing up from a fountain, and falling down again; but though I uſed all my endeavours to convince him of the truth of what I advanced, yet this learned Gentleman refuſed to give credit to my words, declaring that he could not form any conception of the matters which I related.

This Gentleman's incredulity took up much of my thoughts, particularly upon a time when I had got ſome very ſmall eels, not longer than one's little finger: and on this occaſion I ſent for a limner, who I knew was a very curious obſerver, and had a very acute ſight, judging that he would be able to make a drawing of ſome of thoſe blood-veſſels.

I then put one of theſe ſmall eels into a glaſs tube, about the ſize of a gooſe-quill, and placing it before the microſcope, I delivered it into the limner's hands, deſiring him particularly to attend to the current of blood which at that time was moſt diſtinctly to be ſeen in

ſome ſmall veſſels; deſiring him, at the ſame time, to obſerve, that all thoſe veſſels through which the blood was driven outwards to the extremities, were named arteries, but where the blood, when arrived at the ſmalleſt veſſels, began to take its courſe back again, there they were called veins, although it plainly appeared that the veſſels were one and the ſame.

The limner could not ſufficiently admire this ſpectacle of the blood circulating in ſuch minute veſſels, ariſing out of the larger ones; and he was equally in admiration at the blood's returning from thoſe very ſmall veſſels into the larger. And as the eel continued quiet longer than uſual, without moving its tail, I frequently deſired the limner that he would, as long as poſſible, keep his eye fixed on this current of the blood, in order to imprint the idea on his memory. At length, he put his hand to paper, and made a rough ſketch of ſome blood-veſſels and their ramifications, or branches; and he repeated his obſervation and his drawing, until he had compleatly traced ſix ſeveral blood-veſſels, namely, three arteries, and as many veins, with their ramifications, with all the accuracy he was able, ſaying, he had now ſufficient materials to make a perfect drawing, ſo as to deſcribe the exact proportion both of the larger and ſmaller veſſels.

In Plate IV. *fig.* 7, and in the ſpace between 1, 2, 3, 4, are repreſented ſix of theſe blood-veſſels, which I directed to be drawn on rather a larger ſcale than the firſt ſketch taken of them, in order that the ſeveral veſſels might be eaſier diſtinguiſhed; therefore this figure ſhews them about twice as large as they appeared to the limner through the microſcope.

Theſe veſſels were not at the very extremity of the fiſh's tail, but a little below it, towards the end of the fin. And that part, or ſpot, which the limner ſaw through the microſcope, and the ſeveral blood-veſſels of which he made the drawing, did not, in my judgment, take up as much ſpace as is occupied by a large grain of ſand; for though the view of the microſcope might include the compaſs of four ſuch

grains, yet the part wherein the blood-veſſels were ſeen, did not amount to a fourth of that ſpace; ſo that, within leſs compaſs than that of a grain of ſand, there are found to be in the tail of an eel, as great a number of blood-veſſels as are here repreſented between 1, 2, 3, 4.

At the letter A, is repreſented one of thoſe blood-veſſels, which are called veins; B, one of thoſe named arteries; C, is a vein; D, an artery; E, another vein, and F, another artery.

But, in order more clearly to explain the courſe of the blood in theſe veſſels, and to ſhew, at what part, though in fact they are one and the ſame, they aſſume different names, I have in the figure more particularly pointed out, and ſhall now deſcribe one of thoſe veſſels called an artery.

D, is that artery, out of which, at G, proceeds a ſmall branch, which, at H, divides itſelf into two, as HIK: and here we ſee, that the branch GHI is properly to be named an artery, becauſe, as far as I, the blood is driven from the heart, and IK, we muſt name a vein, becauſe, from I to K the blood is brought back towards the heart. In the other branch, which proceeds from H, in the direction HLM, the blood is infuſed into the vein E at M; and ſince at M it firſt begins to take its courſe towards the heart, it follows that at M this veſſel firſt aſſumes the name of a vein.

In this ſmall artery GH, it is to be obſerved that the limner has been very accurate in deſcribing the exact ſize of the veſſel, and we muſt always bear in mind, that in theſe branchings, or ramifications, the arteries grow ſmaller and ſmaller, and the veins continually grow larger, as they receive the blood from the arteries. Farther, all the minute blood-veſſels deſcribed in this figure the limner has repreſented, not by lines, but by ſmall circular dots, ſo as to give an idea of the particles or globules of blood, which he very diſtinctly ſaw, running or paſſing through them.

All the minute veſſels which are repreſented in this figure, of the

ſize pictured at HIK, or HLM, are of equal dimenſions, and they are ſo ſlender, that I can ſafely affirm, that if a grain of our common ſcowering ſand were divided into a million of equal parts, each of thoſe parts would ſtill be too large to find a paſſage through theſe minute veſſels. Which being conſidered, we may conclude how exquiſitely ſlender muſt be the veſſels in which the circulation is performed: and if it were not ſo, how could all the parts of our bodies be continually ſupplied with nouriſhment? *

Farther, in the before-mentioned artery D, is another ſmall ramification at N, which depoſits its contents in the vein E at O, and a little higher, at P, is a branch which unites itſelf with the vein E at Q.

At R, may be obſerved another ſmall branch, proceeding from the ſame artery D, which, at S, is joined with a ſmall branch from the artery B, and afterwards both fall into the vein C.

Again, at T, is another ſmall branch, ariſing out of the artery D, which, at V, ſubdivides itſelf into two, and, in two ſeveral places, namely, at W and X, conveys the blood into the vein E, and from the ſame artery another branch ariſes at Y, which, at Z, is divided into two, and theſe are united to the vein C at the places marked *a* and *b*.

At a ſmall diſtance from Y, is another very minute branch at *c*, which is joined to the vein C at *d*.

Farther, at *e*, another ſmall artery branches forth from D, taking the direction *ef*, and at *f* is ſubdivided into two ſtill ſmaller branches, both which join the vein E at *g* and *h*.

* A very eminent phyſician of our own country, (Dr Mead) expreſſes himſelf in very nearly the ſame words: "Every animal machine is of ſuch a nature, that there is a "ſort of infinity in its conſtituent parts, by which expreſſion I mean, that their fibres are "ſo extremely ſmall, that we cannot diſcover the ultimate ſtamina, even by the aſſiſtance "of the beſt microſcopes. Had it been otherwiſe, aliment could not be conveyed to "every individual part of the body; nor could the neceſſary functions of life be per-"formed. MEAD'S *Medical Precepts, in the Introduction.*

A little higher in the artery D, a ſmall artery branches off at *i*, proceeding to *k* and *l*, where it again divides itſelf into two, and joins the vein E at *m* and *n*.

Cloſe to *i*, two ſmall branches ariſe at *o*, and join the vein C at *p* and *q*.

At *r* ariſes another ſmall artery *r s*, which at *s* divides into two ſmaller branches, one of them taking the courſe *s t*, to join the vein C, and the other paſſing by *s u w x*, to join the vein E.

Laſtly, the extremity, or ſmalleſt part of the artery D, is ſhewn at *r y z*, and is united to the vein E at A, firſt ſending off a branch near the letter *u*, which taking the direction *u b*, is united to the vein C at *t*.

Hence it plainly appears, how many various branches or minute arteries proceed from thoſe ſmall blood-veſſels, or arteries, repreſented at B, D and F, and how theſe all unite with the other ſmall veſſels called veins, which are ſhewn at A, C and E; and this alſo proves what has been ſo often mentioned, that all theſe blood-veſſels, though called by different names, are yet the ſame identical veſſels. And if we reflect, that each of theſe very ſmall veſſels muſt be formed with the ſame kind of coat as the larger ones though of a thinneſs proportioned to its ſize; and farther, if we conſider of what wonderfully fine and inviſible membranes the coats of the ſmalleſt veſſels muſt be formed, and how eaſily the fineſt part of the arterial blood may find a paſſage through thoſe coats, to the end that every part of the body may, from thence, be continually ſupplied with neceſſary and ſuitable nouriſhment; theſe things, I ſay, being duly weighed and conſidered, it ſeems clear that the arterial blood, coming from the heart, muſt contain more ſubtile and fluid parts than when in its paſſage to the heart. For the blood will not be deprived of its more ſubtile juices, while in the larger arteries; to prevent which, I imagine that they are provided with thick and ſolid coats. And here the particles of blood from which its redneſs proceeds, ſwimming in a thin juice, are of a bright red colour; but

in the ſmalleſt arteries, ſome of its parts are drawn off for the ſupport and nouriſhment of the body, whereby the blood, when returning in the veins, being deprived of thoſe thin juices, aſſumes a darker red, and as more of the thin juices are taken away, it will appear blackiſh.

The circulation of the blood is repreſented in another view, at *fig.* 8, A B C D E F G H I K, which is a drawing of ſome veſſels ſeen by the microſcope, in the tail of a tadpole; theſe animals are much quieter than eels, and the arteries and veins are as eaſily to be ſeen in them as in any other creature; and in the ſmalleſt veſſels where the period, or the retrograde motion of the blood is performed, its particles are more diſtant from each other than in any other animal.

The veſſel, ſhewn in this figure, (which was an artery, wherein the blood was driven forward with great ſwiftneſs from A to B) was rather larger than to admit one of the particles of blood at a time. At B it divided itſelf into two branches, which are repreſented at B C and B E; theſe two branches were at D again united in one, for a ſhort ſpace, and at F they again ſeparated, as ſhewn at F G and F I. Here theſe two arterial branches, making a ſmall curve, or bend, again joined in one at H, forming a ſomewhat larger veſſel, which is ſeen at H K; and at K, this was joined to a ſtill larger blood-veſſel.

Here it is plain, that the veſſels A B C D E F G, and A B E F I, foraſmuch as in them the blood is driven from the heart, to G and I, its greateſt diſtance, muſt be named arteries; and the veſſels G H K and I H K, becauſe in them the blood is returning to the heart, muſt be named veins.

I formerly was of opinion, that in all caſes where by an accidental fall or blow, there were produced livid or purple ſpots upon the ſkin, which proceeded from coagulated blood, this blood (if no exulceration ſhould take place in the part) would by degrees be ſo diſſolved, as to be carried off by perſpiration; but the following ſervations cauſed me to alter my opinion in this reſpect.

In the tail of this tadpole, I obſerved a veſſel, of a ſize to admit twenty of the particles or globules at once; ſo that this was a large veſſel, in proportion to thoſe which I have before deſcribed. A ſmall part of it is repreſented at *fig.* 9, L M; and from this, proceeded a minute veſſel, which is ſhewn at M O.

The current in this veſſel, from L to M, was not ſo ſwift as I obſerved in the other veſſels, and for this reaſon, that, in another part of it, at R, the blood was coagulated, inſomuch, that no diſtinct particles could be perceived in it, but only an uniform redneſs; but in the ſmall veſſel N, the current was as ſwift as in any of the others.

In conſequence of this ſtagnation at R, the blood was driven forwards from M to P, with every pulſation of the heart, and inſtantly ran back again, in like manner, as if with the naked eye we beheld a ſwift alternate or reciprocal motion, like that of a ſaw.

We know, that water cannot be compreſſed into a leſs ſpace than it naturally occupies; and this being alſo the caſe with regard to the blood, we muſt conclude, that the coat of this veſſel, between N and P, and alſo a little below N, was, at every pulſation, expanded in diameter, and, at the intermitting of the pulſation, would contract itſelf, and ſo drive the blood back again.

Keeping my eye fixed on the object, I perceived, in a little time, the blood between P and R begin to move, and by little and little, from P towards R, to have the ſame alternate motion to and fro, as I have before deſcribed. At the ſame time, the blood in the veſſel N S, where, at firſt, little or no motion could be ſeen, the current was now as ſwift as uſual. And in the ſmall blood-veſſel, marked P Q, which was only of a ſize to admit one globule at a time, and wherein I could not at firſt diſcover any motion, the circulation was now reſtored; but the particles of blood were few in number, and at a diſtance from each other.

At length all the blood from P to R, was ſo far rendered fluid, that, at every pulſation, it was driven forward, and then returned back again. In theſe obſervations, about two minutes of time elapſed, and my eye being fatigued, I took it off the object to give it reſt, in which interval, the animal put itſelf into a violent agitation, thereby precluding any farther obſervation.

But, ſince we now clearly ſee, that coagulated blood can, by the pulſation of the heart, in courſe of time, not only be put in motion, but alſo ſo far diſſolved, that its component particles or globules may re-aſſume their priſtine figure, we may fairly conclude, that blood, in any animal, which by a blow or bruiſe, is made to coagulate and ſtagnate in the veſſels, may, in the ſpace of ſome days, be reſtored to motion.

60
75

4500 an hour.
24

18000
90

108,000 a day and a night.
10

1,080,000 ten days.

For, ſuppoſing, that in an human body, the blood is driven from the heart ſeventy-five times in the ſpace of a minute (ſome ſay the number of pulſations does not exceed ſixty, but I believe my computation to be neareſt the truth) it follows, that the pulſations in an hour's time, are 4,500, and, in the ſpace of a day and a night, 108,000.

Now, if we find, that the appearance produced by coagulated blood, will, in the ſpace of ten days diſappear, from our bodies, and conſider, that, in the ſame ſpace of time, a million and eighty thouſand pulſations are performed, and ſuppoſing, that, at every pulſation, ſo much of the blood is put in motion in the ſeveral veſſels, as is only equal in ſize to a grain of ſand, we may gather how much of ſtagnant blood may be reſtored to motion, in the ſpace of time juſt mentioned.

For example, let us ſuppoſe, that the quantity of blood, which at every pulſation can be rendered fluid, and reſtored to its motion, is no more than the ſize or quantity of a grain of ſand, and that eighty of ſuch grains placed ſide by ſide do not exceed the length of one inch; we find then that 512000 grains of ſand taken together are equal to a cubic inch, which number is not the half of the number above aſſigned.

80
80
6400
80
512000

In this blood-veſſel, which I have juſt mentioned, I could not only very clearly diſcern the ſeveral pulſations, but I could alſo many times in all the arteries, ſee to make an exact computation how many times the blood was propelled from the heart in the ſpace of one minute.

Now, if we conſider that ſo great a quantity of blood, as is contained within the compaſs of a cubic inch, is very rarely by a blow or bruiſe congealed in one ſpot, we may eaſily conceive, that when a coagulation does happen, it may, by ſuch frequent propulſions or pulſations as I have mentioned, be at length diſſolved, and in all, or moſt of the veſſels, reſtored to the ſame current or courſe as before.

At another time, I obſerved an appearance of a different nature in the blood-veſſels, which was occaſioned by my having put a tadpole into a piece of clean paper, whereby a ſmall ſpot in the very thinneſt part of its tail ſtuck to the paper, and thereby received a ſmall injury, ſo that ſome blood flowed from the wound, out of an artery which was of a ſize to admit about four globules of blood to paſs through it at a time.

The blood thus flowing out, remained collected about the wounded part; but here another ſight preſented itſelf, which engaged all my attention; for, in this ſame artery, at about the half of an hair's breadth diſtance from the wounded part, another ſmall branch appeared, wherein the blood purſued its courſe in the ſame uniform and diſtinct manner, as if the artery had remained uninjured.

At *fg.* 10, T V, is ſeen this artery, which was wounded a little above V. The letters V and X indicate the extravaſated blood. V W denote the minute artery in which the blood purſued its regular courſe, though cloſe to the place, at P, it iſſued out from the artery T V.

This ſight at firſt ſurprized me, but my wonder ceaſed when I obſerved that this blood veſſel V W, was united with a large one at W, and of that ſort which, carrying back the blood to the heart, is called a vein. And by means of this laſt-mentioned veſſel, the blood was carried through the paſſage V W, as it were, by a kind of ſuction, with as much ſwiftneſs as it had been before driven from T to V, inſomuch that I was perſuaded, that if the ſmall veſſel V had not been united to the artery T V, but only its orifice had laid in the extravaſated blood, about the ſpot at V, that ſuch extravaſated blood would in a ſhort time have been, as I may ſay, ſucked up and carried away with the remainder of the blood towards W.

I have often reflected on the nature of thoſe very thin tranſparent pellicles, or ſkins, which conſtitute the wings of ſmall flying inſects, ſuch as gnats, flies, moths, and the like; ſome of which I have obſerved to be entirely covered with feathers, others compoſed only of thoſe muſcular parts which ſtrengthen and expand the wing, and others are wholly covered with hairs: and when I conſidered, that theſe hairs, or feathers, are fixed or rooted in regular order in the membrane of the wing, my thoughts were wholly bent to diſcover how theſe wings might be formed.

As to the ſuppoſition which at firſt occured, that theſe membranes were compoſed of a tranſparent viſcous or gummy matter, congealed or hardened to a due conſiſtence, I could not ſatisfy myſelf with that idea, for it ſeemed impoſſible to me, that in that caſe the feathers and hairs could be produced in ſuch regular order; and yet, it was beyond my comprehenſion how ſo thin a membrane could be furniſh-

ed with ſuch a number of veins or veſſels as would be requiſite for the formation of ſuch feathers and hairs.

In my endeavours to inveſtigate this ſubject, I firſt examined one of thoſe flying inſects, whoſe wings conſiſt of membranes only, without either hairs or feathers; which membranes are placed between the large veſſels and ſinews, giving ſtrength and ſtiffneſs to the wings; and upon the examination of theſe, I plainly ſaw that there were large blood-veſſels running among the ſinews or muſcular parts, from which aroſe ſmaller veſſels, and theſe again divided themſelves into ſtill ſmaller ones, until at length they became inviſible.

I was not, however, content with this, and among other objects, I met with a large green graſshopper, in the wing of which I more clearly perceived not only, that from the large blood-veſſels in the wing, other ſmaller ones aroſe, but I alſo ſaw that the colour of the blood in theſe large veſſels was green; and in the ſmaller veſſels and their more minute ramifications, I could ſtill diſtinguiſh the blood to have a greeniſh caſt; but when theſe veſſels were again ſubdivided into ſmaller ones, I could not perceive any colour in them, and the veſſels themſelves became ſo clear and tranſparent that they entirely eſcaped the ſight.

Though I could moſt plainly ſee that the ſubſtance, or matter, of which this blood was compoſed, conſiſted of globules ſwimming in a clear liquor, I moreover cut the wing in two, and out of the veſſels collected ſome of the blood, which I placed before the microſcope, and obſerved that where the globules or particles of it lay in numbers or heaps together, the colour was a lively green, where they lay ſo thin as not to amount to the twentieth part of the thickneſs of an hair of one's head, the colour was only greeniſh, but where the globules were ſingly diſperſed, it had no longer any appearance of colour at all, but became tranſparent; and here it clearly appeared

to me, that all theſe green globules were contained in a thin tranſparent fluid.

From theſe obſervations I concluded, that the tranſparent membranes which principally conſtitute the wings of theſe ſmall animals, are as completely provided with blood-veſſels, ſinews, &c. as the bodies of other creatures.

I formerly was of opinion, that in the wings of theſe ſmall flying creatures there was no circulation of the blood, for I judged, that in its paſſage through ſuch exceeding ſlender veſſels, it muſt be evaporated or dried up: and the rather, as many of theſe winged inſects do not take any food, but only live a few days, and die as ſoon as they have coupled, and laid their eggs. But if we recollect, that the membranes of their wings are of a hard and horny nature, though exceeding thin, we may conclude, that all the veſſels, compoſing this horny membrane are ſo firm and tough, that, though all the fluid contained in them ſhould be dried up by the heat of the ſun, the veſſels themſelves would not collapſe or ſhrink up, as thoſe in our own bodies, or the bodies of other animals would do in the like caſe.

I was confirmed in this opinion, by obſerving that the blood-veſſels in the wings of theſe inſects were not of the ſame make as thoſe in the bodies of the human ſpecies and of terreſtrial animals, but were compoſed of annular parts, or rings, like the windpipe and the veſſels pertaining to reſpiration in the lungs of animals. And, though we may not be able to diſcover all theſe veſſels in the wings of inſects, yet we may be aſſured that there is an incredible number of them entering into the compoſition of thoſe wings. And, ſhould we imagine, that theſe veſſels by reaſon of their ſmallneſs or their hard and dry nature, are impervious to blood and juices for the ſuſtenance of the wing, we muſt conſider that there is not a ſingle hair or feather, how ſmall ſoever it be, which is found upon one of theſe wings, but muſt have had in it many ſmall veſſels neceſſary for its production; for every feather has its quill and every quill muſt have a great num-

ber of veſſels, in order to contribute to the increaſe of ſuch feather: and who knows whether each of ſuch ſmall feathers may not have been formed out of more than a thouſand veſſels? And when we reflect on the great number of feathers or hairs with which the wing of a fly or moth is covered, we ſhall find it impoſſible to conceive the numbers of veſſels of which theſe inſects, though they appear contemptible in our eyes, are compoſed. Indeed, I am of opinion, that many phyſicians and ſurgeons cannot reckon up ſo great a number of veſſels in a cat or a dog, as I imagine enter into the compoſition of a gnat.

It was alſo at one time my opinion, that the ridges, or thicker parts, in the wings of theſe flying inſects, and which I have named ſinews, were only the boney parts of the wing to give it ſtrength. But when I perceived, that there were large blood-veſſels in thoſe parts, I applied myſelf with all diligence to diſcover, if poſſible, the current of blood in thoſe veſſels.

For this purpoſe, I took thoſe butterflies which proceed from the catterpillar that feeds on the aſpin, the poplar, or the willow; and which, in ſize and ſhape, reſemble the ſilk worm's butterfly. Their wings are, on both ſides, covered with white feathers, and, unleſs theſe are taken off, the membrane cannot be diſcerned. Theſe feathers I wiped from the wing with a ſoft piece of leather, as gently as poſſible, to avoid injuring the wing or hurting the butterfly. And I then applied the wing (while the animal was alive) to the microſcope; but, with all my attention, I could not diſcern the leaſt current of blood in the veſſels, though if there had been any regular motion, I have no doubt but I ſhould have ſeen it, and the rather, as this blood was of a yellowiſh colour; and, upon opening the large veſſels in theſe wings, I have often preſſed out the blood which they contained.

For the moſt part, theſe large veſſels lye in, or near, that boney part of the wing which gives it ſtrength; and I have often obſerved

thoſe veſſels to be placed, not in a right line, or parallel with the boney part, but twiſted, with various turnings, in like manner as if one were to ſee the inteſtines of an animal in the poſture they lie while joined to their membranes.

After this, I accidently met with a large grey moth or butterfly, which in a manner flew into my hand. This butterfly I killed, and cut off the wings, and, having taken off the feathers, I placed them before the microſcope: and here I ſaw the blood-veſſels more plainly than in the wings of the other inſects I have mentioned. A part of one of theſe wings I placed before the microſcope, and cauſed a drawing to be made, not only of thoſe blood-veſſels lying in the boney part of the wing, but alſo of thoſe which were diſperſed over the membrane, and of which the membrane, in part, conſiſts; in order to ſhew, how the veſſels lye twiſted in various turnings; alſo, how they are compoſed of annular parts or rings placed together; and likewiſe, how, from theſe large veſſels ſmaller branches ariſe, which, in great numbers, are ſpread all over the membrane.

In Plate IV. *fig.* 11, P Q R repreſents a blood-veſſel, with its various branches, ſpread over the membrane. A B C D E F G, is a large blood-veſſel in one of the boney parts of the wing, wherein is ſeen, the manner how this veſſel is twiſted or bent, and alſo, the annular parts of which it is compoſed; in conformity with the formation of the blood-veſſels in all inſects; inſomuch that I have ſeen the blood-veſſels in the louſe and flea, to be compoſed of ſuch annular parts.

In the ſame figure, B H, I K, C L, D M, E N, and E O, repreſent the blood-veſſels with their branches iſſuing from this laſt-mentioned veſſel, and ſpreading over the membrane; and in theſe alſo, the annular parts could be diſtinguiſhed; but when they became ſo ſmall, as to appear no larger through the microſcope, than a horſe-hair to the naked eye, then the rings in them could no longer be diſcerned. Theſe veſſels the limner purſued in his

drawing as far as his eye could diſtinguiſh them, but at length they became ſo minute, and ſo intermixed one with another, that no true judgment could be formed of them.

In S T V, are ſhewn a few of the feathers, which ſo exactly cover both ſides of the membrane, that no part of it can be ſeen. W W W, are three larger feathers which were placed on the edges of the wing. XXXXX indicate the membrane, when it was laid bare of its feathers, on both ſides, in order to diſcover the blood-veſſels. And here, though not in regular order, may be ſeen the cavities or holes in which the quills were fixed, and from which they had their origin.

Farther, I conſidered with myſelf, whether or no the blood-veſſels conſiſted of arteries and veins; but I could not ſee any other than one ſort of veſſels in the wings of all the inſects of this ſpecies, which I have examined, except that once I thought I ſaw in the thinneſt part of the wing of a graſshopper, that in the larger veſſels next the body, another ſpecies of veſſels was inſerted.

The concluſion drawn by me upon the whole was, that there was not any circulation of the blood in the wings of theſe creatures, and that the blood-veſſels I have been deſcribing, which certainly were arteries, were only deſigned to perfect the formation of the wing with its multitudes of feathers, and afterwards, to convey the blood, with an exceeding ſlow motion, through the veſſels, in order to afford a ſmall degree of ſupport to the wing in its perfect ſtate. For, as theſe butterflies, and thoſe which are produced from the ſilk-worm, and many other flying inſects which proceed from caterpillars, do not take any food, and do not live any longer than till they have coupled and laid their eggs, it is not neceſſary, in my opinion, that the blood in their wings ſhould have any circulating or retrograde motion, and beſides, the membranes being of a ſtiff horny nature, they require little or no nouriſhment.

I cannot here omit to mention, that I have heretofore often taken

great pains to diſcover two kinds of veſſels in the leaves of trees and plants in order to aſcertain, whether there was any circulation in leaves, but I never could ſee more than one ſpecies of veſſels, namely thoſe that convey the nutritive juices to the ſeveral parts.

But, if we conſider, that not only the leaves of trees, but alſo their fruits, do not need any other than thoſe nutritive juices, which are requiſite to bring them to perfection, we ſhall not wonder that when at a ſtate of maturity, they are, as it were, ſpontaneouſly looſened or ſhaken off from the tree, without the leaſt appearance of having been broken off; nay, that part of the ſtalk which was originally united to the tree, will appear as ſmooth as if, with its multitude of veſſels, it never had been joined to it.

In a word, I will venture to aſſert, that neither the wings of the before mentioned flying inſects, nor the leaves or fruit of trees, require that kind of circulation of the juices, which we have been conſidering.

Of the formation of the Teeth in ſeveral animals; the ſtructure of the human Teeth explained, and ſome of the diſorders to which the ſame are liable accounted for.

HAVING taken great pains to inveſtigate the formation of the elephant's tooth, and examined into the nature of it by every means I could deviſe, I found it to conſiſt only of a collection of tubuli, or pipes, which are exceedingly ſmall, and all derive their origin from the inner part of the tooth, for I never could diſcover any of them lying longitudinally or lengthwiſe in it.

Upon examining that part of the tooth where the boney ſubſtance is but thin, which is where it is united to the head, I very plainly perceived that one end of theſe tubuli took its riſe from the cavity within, and the other end extended to the circumference, which circumference or outſide was compoſed of a kind of ſcaly particles laid one on another, and I conſidered with myſelf whether each ſeries or layer of theſe ſcaly particles might not be the ſubſtance or thickneſs formed in the ſpace of one year.

Purſuing theſe my obſervations in the examination of that part of the tooth where to the eye it ſeems perfectly ſolid, I there found it to have, near the middle, a ſmall cavity, through which cavity I concluded the nutritive ſubſtance muſt be conveyed, for the continual ſupport and increaſe of the tooth. And upon examining the tubuli round about this ſmall cavity, I perceived that they all aroſe from thence, and ſpread themſelves all round towards the circumference. I endeavoured to examine ſtill farther, beyond the part where this cavity ended, in order to diſcover whether from theſe firſt formed

tubuli others might not ariſe or branch forth ; but this part of nature's work was inſcrutable to me. My conjecture reſpecting the matter however was, that each of the boney tubuli (proceeding from the ſmall cavity before mentioned) might be compoſed of many folds or coats, and thus not only be diſpoſed to diverge or ſpread into a larger ſpace, ſo as to form the ſubſtance of the tooth, but alſo, by this means, contribute to its ſtrength.

I alſo examined the teeth taken from young hogs, and found them to be likewiſe formed of tubuli ſpreading from the cavity in the center, to the circumference.

After this, I was deſirous of examining the ſtructure of the human teeth, and having for that purpoſe procured a number of the large ones, called the grinders, I found them to be formed exactly in the manner before deſcribed, namely, of tubuli or little boney pipes, cloſely joined together, ariſing at the cavity in the middle of the tooth, and ending at the circumference or outſide. And in order to explain this formation to the Reader as clearly as poſſible, I cauſed the following drawings to be made :

In Plate V. *fig.* 1, at A B C, is repreſented a human tooth, on one ſide of which, with a file, I cut away almoſt the half, not to diſcover the cavity therein, which is well known to moſt perſons, but only to ſhew the manner how the tubuli, of which the boney part is compoſed, take their riſe from the cavity in the center, and terminate at the circumference. But it muſt be underſtood, that theſe tubuli are by no means of the ſize repreſented by the lines in this figure, the ſame only denoting the order in which they lie, for the tubuli themſelves are exceedingly ſmall, and cannot be well diſcerned without the help of the very beſt microſcopes.

In the ſame figure, at G H I, is repreſented another tooth, which is filed down from the upper part of it as far as the before-mentioned cavity, in order to ſhew how the tubuli do here alſo ſpread themſelves round about from the center. All the extremities of the

tubuli which lie near the outſide of the tooth, (as far as they are above the gums, and expoſed to the air) are extremely hard, being as it were the ſolid caſe, ſhell, or covering of the tooth: and if we examine the ſurface of this caſe or covering attentively, we ſhall find one tooth to have forty, another perhaps fifty circles on it, like wrinkles, or gatherings, which in ſome places run in a curved or wavy direction, as is repreſented in the figure at D E F, where a drawing is given of this outſide ſhell, with ſome of the circles marked thereon; and I imagine that the circles which thus appear like wrinkles proceed from hence, that they are the places where the tooth, while growing, is from time to time protruded or thruſt out from the gum.

In the teeth ſhed by children, and likewiſe in thoſe of many young animals, I have obſerved that the ends of their roots are entirely open or hollow; and in like manner I imagine that the roots of the molar teeth or grinders which I have been juſt deſcribing, are at firſt formed in the ſame manner, but that in proceſs of time they become oſſified or converted into a boney ſubſtance, of a ſpongy nature, through which many veſſels paſs, conveying blood, and nutritive juices into the cavity of the tooth, and I alſo conceive that this cavity is filled with nerves and veſſels ſpreading themſelves into ſo many branches, that every one of the boney tubuli is thereby increaſed during the time of its growth, and afterwards, (while the tooth continues ſound) nouriſhed and ſupported. I alſo conjecture that theſe ſmall veſſels thus nouriſhing and ſupporting the boney tubuli do not end at the ſurface of the tooth (I mean, in that part of it which is within the gum) but that the aliment or nutritive ſubſtance has a continued courſe through theſe veſſels, and that the ends of the boney tubuli are again converted into ſoft or pliable veſſels, ſpreading through the gum, and that thoſe veſſels are what principally keep the tooth fixed in its place.

The firſt formation, and ſubſequent ſupport or nouriſhment of the

tooth being as before deſcribed, we may eaſily conceive that the boney tubuli, (being of a ſolid nature, and incapable of dilatation or ſpreading) may happen to be obſtructed by ſome groſs or concreted matter, and then the ſmall veſſels contained within the cavity of the tooth muſt immediately by ſuch obſtruction in the circulation of their juices be deſtined. This diſtention or ſwelling will neceſſarily excite great pain, for all the veſſels contained in the tooth will preſs cloſely on each other, foraſmuch as they cannot ſwell or ſpread themſelves as other veſſels can, which are not confined within the ſolid ſubſtance of a bone. Again, ſuppoſing theſe boney tubuli to be obſtructed, and the obſtruction not removed, we may from thence gather the reaſon why our teeth partially decay, ſometimes on the ſides, and ſometimes at the tops, the reſt of the teeth remaining ſound for ſeveral years after.

In order to ſhew the proportion which the ſize or thickneſs of the tooth bears to its component parts before deſcribed, I placed a very ſmall piece of this tooth before the microſcope, and delivered that microſcope to the limner, directing him to draw an exact repreſentation of what he ſaw, (but without acquainting him what that object was). And here I muſt obſerve, that in this tooth the tubuli appeared to me much larger than I had before obſerved in any animal, or in the elephant's tooth.

In Plate V. at *fig.* 2, K L M N, is repreſented * an exceeding ſmall particle, or piece of a human tooth, of that ſort called the molar teeth, or grinders, as ſeen through the microſcope. The reaſon why in this figure ſome of the tubuli there pictured appear of a darker ſhade than the reſt, is only this, that in that place where they ſeem darker there were more of the tubuli lying one

* The author having juſt below informed us, that 120 of the boney tubuli make only the forty-fifth part of an inch, we may, by counting the tubuli repreſented in this figure, judge the natural ſize of the fragment, or piece of tooth here magnified, and it will be found to be about the fortieth part of an inch in length and the fiftieth part of an inch in breadth, or of the ſize ſhewn at X.

behind the other, owing to the piece of tooth being thicker in that part, for this ſmall fragment was ſplit off, and not cut from the tooth.

The breadth of this tooth was almoſt two fifth parts of an inch, and from the beſt computation I could make, I judged that within the forty-fifth part of an inch, I ſaw an hundred and twenty of the tubuli, which amounts, in the ſpace of one inch in length, to five thouſand four hundred: now ſuppoſing this molar tooth, or grinder, before deſcribed, to be of a round figure, the diameter of it would be 2150 times the thickneſs of one of the tubili of which the ſame is compoſed, and when this number is multiplied into itſelf, the product is 4,822,500. In a word, the proportion of one of the boney tubili to the ſize of ſuch a tooth, is as one to 4,822,500

Notwithſtanding I had now obtained a very ſatisfactory inſight into the formation of the human tooth, I was not yet content, but became deſirous to examine into the nature of the ſubſtance, or veſſels contained in the cavity, and for this purpoſe, I procured ſome of the fore teeth, and the jaw-bone of an ox, which were taken out and brought to me immediately after the animal had been killed; ſeveral of theſe fore-teeth, and ſome of the grinders, I broke, or ſplit open, and with great admiration obſerved, that thoſe veſſels, which, paſſing through ſmall apertures in the lower part of the tooth, filled all the cavity within, conſiſted of ſuch an inconceivable number of blood-veſſels, and other veſſels, as to ſurpaſs all imagination: indeed, many of them I obſerved to be as ſmall and ſlender as the tubili themſelves, of which the tooth was formed; and among them were ſmall blood-veſſels branching out into ſtill ſmaller ones, many of them entirely colourleſs; therefore, I thought it probable that there might be ſtill ſmaller veſſels entirely undiſcernible by our ſight.

All theſe veſſels were incloſed in a membrane, or coat, which was eaſily to be ſeparated from the bone, and, having kept ſome

of theſe teeth by me four or five days before I broke them open, (in which time all the internal moiſture was evaporated), I obſerved in ſome places within the tooth, a bloody ſubſtance which had penetrated into the boney tubuli, giving ſome of them a reddiſh colour.

It is my cuſtom, every morning, to rub my teeth with ſalt, and afterwards to waſh my mouth, and after eating I always clean my large teeth with a tooth-pick, and ſometimes rub them very hard with a cloth. By theſe means, my teeth are ſo clean and white, that few perſons of my age * can ſhew ſo good a ſet, nor do my gums ever bleed, although I rub them hard with ſalt; and yet I cannot keep my teeth ſo clean, but that upon examining them with a magnifying glaſs, I have obſerved a ſort of white ſubſtance collected between them, in conſiſtence like a mixture of flour and water. In reflecting on this ſubſtance, I thought it probable, (though I could not obſerve any motion in it,) that it might contain ſome living creatures. Having therefore mixed it with rain water, which I knew was perfectly pure, I found, to my great ſurpriſe, that it contained many very ſmall animalcules, the motions of which were very pleaſing to behold. The largeſt ſort of them is repreſented in Plate V. *fig.* 3, at A, and theſe had the greateſt, and the quickeſt motion, leaping about in the fluid, like the fiſh called a Jack; the number of theſe was very ſmall. The ſecond ſort are repreſented at B, theſe often had a kind of whirling motion, and ſometimes moved in the direction repreſented by the dotted line C D, theſe were more in number. Of the third ſort, I could not well aſcertain the figure, for ſometimes they ſeemed roundiſh but oblong, and ſometimes perfectly round. Theſe were ſo ſmall, that they did not appear larger than repreſented at E. The motion of theſe little creatures, one among another, may be imagined like that of a great number of gnats, or flies ſporting in the air. From the appearance of theſe, to me, I

* Mr. Leeuwenhoek, at the time of writing this, was upwards of fifty years of age.

judged that I ſaw ſome thouſands of them in a portion of liquid, no larger than a grain of ſand, and this liquid conſiſted of eight parts water, and one part only of the before-mentioned ſubſtance taken from the teeth.

With the point of a needle, I took ſome of the ſame kind of ſubſtance from the teeth of two ladies, who I knew were very punctual in cleaning them every day, and therein I obſerved as many of theſe animalcules as I have juſt mentioned. I alſo ſaw the ſame in the white ſubſtance taken from the teeth of a boy about eight years old; and upon examining in like manner, the ſame ſubſtance taken from the teeth of an old gentleman, who was very careleſs about keeping them clean, I found an incredible number of living animalcules, ſwimming about more rapidly than any I had before ſeen, and in ſuch numbers, that the water which contained them, (though but a ſmall portion of the matter taken from the teeth was mixed in it,) ſeemed to be alive.

Some time after making the preceding obſervations, I received from Sir Hans Sloane, a packet, containing three ſmall maggots, two of which were dead, and the third alive, with a letter, informing me that they were found in a perſon's decayed tooth, from whence they had been expelled by fumigation. Upon examining theſe, I had no doubt that they were of the ſort found in cheeſe, and upon comparing them with ſome living ones which I procured from a cheeſemonger, I found them to correſpond exactly in make and ſhape. Theſe maggots are the offspring of a ſmall fly, which is frequently ſeen in cheeſemongers' ſhops, and lays its eggs in the cheeſe, where the little maggots produced from them find nouriſhment, and are in time converted into flies.

The maggots ſent me by the cheeſemonger, I kept in a glaſs tube, and ſupplied them with food, and in a ſhort time they were converted into flies, which laid eggs, and theſe again produced maggots of the ſame kind as the former. The living maggot

which I received from Sir Hans Sloane I kept by itſelf, and it was alſo converted into a fly of the ſame ſpecies.

Theſe maggots when firſt hatched from the egg, are no bigger than a grain of ſand, but afterwards grow to about four times that ſize; they have two ſmall teeth by which they are enabled to gnaw their way into the cheeſe; and as their ſkin is very firm and hard they are not eaſily cruſhed or deſtroyed. Now, it is eaſy to conceive, that the perſon in whoſe tooth the maggots firſt mentioned were found, might have been eating of ſuch old cheeſe, and that the maggots, or the eggs producing them, might have been lodged uninjured in the cavity of the tooth, where, when they began to gnaw, they muſt cauſe great pain; and we may elſo eaſily imagine that by the fumigation they might have been driven out of the part.

ON COFFEE.

IN my inquiries into the nature of ſeveral kinds of ſeeds, I examined, among others, thoſe which are called Coffee Beans, which are much in uſe in this country, for preparing the well known drink of that name.

I was firſt deſirous to know in what part of theſe ſeeds the young plant was placed, and for this purpoſe I procured ſome entire coffee beans, incloſed in their original huſk or ſhell.

In Plate V. *fig.* 4, E, F is repreſented this nut, huſk, or ſhell, in which are two of theſe coffee beans, divided by a membrane, or partition: for, that which at firſt ſight appears as a ſingle ſeed, does in fact conſiſt of two diſtinct beans or ſeeds, lying in regular order beſide each other, juſt as we obſerve two kernels in an almond, a filbert, or an apricot.

In *fig.* 5, G H, is ſhewn the nut or ſhell, opened on one ſide, ſhewing how the two beans lie with their flat ſides next each other; G, is that part which was joined to the plant, and from whence the ſeed derived its nouriſhment, and H, is the end where the young plant is formed in the ſeed: *fig.* 6, I K, is a coffee-bean lying with its flat ſide upwards.

I cut a ſlice from one of theſe beans, at the end marked I, and cauſed a figure of it to be drawn, ſomewhat magnified, only to ſhew the place where the young plant lies.

Fig. 7, L M N, is this ſlice, and at O is to be ſeen the part of the

bean where the young plant is formed; and here that part which would have grown up into a ſtalk or ſtem, is cut tranſverſely.

I have alſo laid coffee beans for ſome time in water, in order more eaſily to take out the young plant, and to give a drawing of it from the microſcope. This young plant, ſo magnified, is ſhewn in Plate V. *fig.* 8, P Q R S T V. At Q R S T V are three compleatly formed leaves, and I could ſee the veſſels and globules whereof they conſiſted very diſtinctly in ſome of them, eſpecially where the leaves did not lie two or three together. A few of theſe globules, compoſing the leaf, are repreſented in this figure, at letter T. That part where the root and ſtem would ſhoot forth is ſhewn at P Q V.

After this young beginning of the plant had ſtood ſome months before the microſcope, I perceived that the leaves were covered with a ſort of mouldineſs. This appearance uſually begins by a kind of ſtalk; from whence a globule proceeds, and out of that many more, exhibiting together the likeneſs of foliage, but the mouldineſs I am now ſpeaking of, had a very different appearance, being much more in the ſhape of flowers, as is ſhewn in *fig.* 8, at a a a a a. But I have often ſeen this mouldineſs, even on the dead bodies or parts of the bodies of inſects, and alſo on the ſhell of a ſilk-worm's egg.

Some of theſe beans I placed in a proper chymical veſſel over the fire, and obſerved, that in the roaſting, or burning them, a great great quantity of oily ſubſtance. and alſo of watery moiſture was expelled. The roaſted beans I broke into ſmall pieces, and after infuſing them in clear rain water, I ſuffered the water to evaporate, after pouring it off from the groſſer parts of the coffee, and then I diſcovered a great number of oblong ſaline particles of different ſizes, (but moſt of them exceedingly minute) all of them with ſharp points at the ends, and thick in the middle.

Afterwards, I took ſome of the coffee beans in the ſame ſtate they

are imported to us, and upon ſqueezing, or preſſing them with great force, a larger quantity of the oil was expreſſed than could be imagined, and I obſerved that this oil was very clear and thin.

I alſo cut coffee beans into very ſmall fragments, or pieces, in every direction, and I always found them to be of a very open and ſpongy texture: for, whereas, almoſt all ſeeds conſiſt of a farinaceous, or mealy ſubſtance, (except in that part where the young plant is contained) this ſeed, on the contrary, is formed of nothing but fibres, branching or ſpreading one among another, and the cavities between them, in many places, filled with oil; for when I cut off very ſmall pieces from the bean, I could plainly perceive the oil, and take it out from the part where it lay.

From the middle of a bean, I cut a very ſmall ſlice, and placed it before the microſcope, in order to ſhew the open and ſpongy texture of this ſeed; and in Plate V. *fig.* 9, A B C D, is repreſented this particle, or piece of bean when magnified, the natural ſize of which was no larger than might be covered by two grains of ſand. The parts which in this figure appear cloſed up, and ſome of them to conſiſt of globules, were filled with oil. When a coffee bean is thus cut into ſmall pieces, and the pieces preſſed between the fingers, or ſqueezed between any hard ſubſtances, the fingers, or whatever is uſed in ſuch preſſure, will be much ſtained with oil; (that is to ſay, in proportion to the force applied) and I will venture to ſay, that by a ſingle operation of this kind, more than one thouſand little drops of oil will be expreſſed: it is here to be noted, that the oily particles formed in the coffee bean are not perfectly of a round figure, but in many places they lie together in irregular ſhapes.

This formation of the coffee bean being conſidered, we need

no longer wonder, that they cannot be reduced into powder until they have been roaſted, or burnt, for, in the roaſting, much of the oil is driven off and conſumed by the fire, and the branchey, or fibrous particles become weaker or more brittle, and the more they are burnt, or roaſted, the more eaſily they can be pounded in a mortar.

As to myſelf, who am accuſtomed to take this kind of drink every morning for breakfaſt, I do not ſuffer the coffee beans to be much burnt, and I cauſe them to be pounded, or reduced into ſuch ſmall particles, that they will paſs through a ſilken ſieve, and until they feel between the fingers as fine and ſmooth as flour. A proper quantity of the coffee thus prepared, being put into a coffee-pot, I pour on it boiling rain water, and then ſet it again on the fire, but not to boil, and after letting it ſtand for a ſhort time to ſettle, this is the coffee I make uſe of.

This is not, indeed, a very profitable way of making coffee, though much more grateful and pleaſant to the palate, except to thoſe who like the burnt flavour. For, when the coffee beans are violently roaſted, they can more eaſily be pounded to powder and paſſed through a ſieve, and the liquor clarifies ſooner; and alſo, by reaſon of the burning, the bitter taſte ſpreads farther, and produces more of the liquor, eſpecially if the coffee be boiled in the water

But, if we judge, that the oil and ſalts which are found in coffee, are the parts wherein its virtue conſiſts, and from which we are to expect benefit to our health, we ſhall prefer that coffee which is not over roaſted, to that which is more burnt, for, in the coffee which I drink, I always obſerve a great quantity of oily particles ſwimming on the ſurface, which would not be found there, if the coffee were more roaſted, for in that caſe the oily particles are more driven off by the force of the fire.

Many perſons ſay, that coffee is not wholeſome, unleſs it is made bright and clear before it be drank; but this, I think, is of no conſequence, becauſe I am well convinced that the particles of coffee, (excepting the oil and ſalts, which I have before mentioned to be contained in it,) are of ſo hard and inflexible a nature, that they never can be introduced into the ſyſtem of our bodies.

I have oftentimes endeavoured to bring coffee beans to a ſtate of growth and vegetation, but herein I never could ſucceed: whether this was, becauſe they had been kept too long, or whether, that at the place of their growth, they had been over dried, to facilitate their exportation to diſtant countries, whereby the juices which ſhould have nouriſhed the young plant were dried away, I cannot pretend to ſay.

I have ſeveral times placed coffee beans in a clean glaſs under water, without finding any alteration in the colour of them or of the water, but when they were ſo placed that part of them was above the ſurface of the water, then both the coffee-beans and the water became of a graſs green colour.

I formerly thought that theſe coffee beans were produced by ſowing them annually in the manner of our peaſe and beans in Europe, but I have been lately informed by a Gentleman who has travelled in the Eaſt, that they are the ſeed or fruit of a tree which grows to about the ſize of our lime trees.*

* The coffee-tree is a native of Arabia, from whence in the laſt and preſent centuries it has been cultivated both in the Eaſt and Weſt Indies, but the Mocha coffee is ſtill in the greateſt eſtimation.

ON VINEGAR.

I HAVE obſerved, that on expoſing a ſmall quantity of white wine Vinegar to the air for a few hours, a vaſt number of corpuſcles, or ſmall ſolid ſubſtances appear in it, which I take on myſelf to name the ſalts of Vinegar. Some of theſe are repreſented in Plate V. *fig.* 10; thoſe at A appeared to terminate in a ſharp point at each end, having in the middle a dark ſpot; others were glittering like cryſtals, as at B, and theſe were moſt in number: others of theſe corpuſcles were of an oblong figure, and of a dark colour, with a lucid ſpot in the middle, as at C; and ſome few of an oval form with an oval bright ſpot in the middle, as at D. Among the figures A, B, D, I was convinced that I ſaw ſeveral with a cavity or hollow in them, which gave them the appearance of being half dark coloured, and half tranſparent. Others of theſe ſalts or cryſtals laid one on another in cluſters, as at E; and laſtly, ſome there were with points at one end only, like half cryſtals, as at F. It is not eaſy to deſcribe the extreme minuteneſs of theſe corpuſcles, and ſome of them were indeed, ſo ſmall that they almoſt eſcaped the view of the microſcope.

All theſe particles, which I name the ſalt of vinegar, I conclude to be thoſe parts of it which excite on the tongue that taſte or ſenſe named acid. And, although they appeared to me, through the microſcope, of the ſhapes and ſizes I have mentioned, yet I concluded that they were all compoſed of ſtill ſmaller particles, of the ſame ſhape, in like manner as I have often in our common ſea-water, or in water wherein common ſalt is diſſolved, when placed before a microſcope, ſeen many particles moſt exactly quadrilateral, or four-ſquare, but ſo minute that millions of

them were not equal to a grain of ſand; and theſe, while I contemplated them, would increaſe in ſize ſtill preſerving their exact ſquare figure. In like manner I conclude, that there are none of theſe ſharp pointed ſalts which I obſerve in vinegar, but are compoſed of numbers of ſmaller particles of ſimilar ſhape.

Having kept in my parlour for about two months, a glaſs, two fingers broad, with a ſmall quantity of vinegar in it, expoſed to the air, I obſerved, at the end of that time, numbers of ſaline particles ſwimming on the ſurface, and, upon more narrowly examining them, I plainly diſcerned, what I had not ſo clearly ſeen before, that theſe ſaline particles had a kind of cavity in them, as eaſily to be ſeen, as if, with the naked eye we were to look into a ſmall boat or a ſhip, and which, the longer the vinegar was ſuffered to ſtand, grew larger: ſome of theſe, with the cavity in front, are repreſented at G, and at H ſome of the ſame ſeen ſideways. I alſo cauſed a drawing to be made of a living eel, of that ſpecies which is often found in vinegar, whereof the number I ſaw in this liquor was very great; this is ſhewn at L M; and at N O, another eel dead, which I killed, on purpoſe that the limner might take it's figure more accurately. Theſe eels (which are inviſible to the naked eye) I cauſed to be drawn, that by comparing them with the before-mentioned ſaline particles, the extreme minuteneſs of thoſe ſalts might be the better conceived, and it ſhould be underſtood, that by far the greater part of theſe ſalts could not be diſcovered by the common microſcope, which made the eels viſible. I am alſo deſirous to convince thoſe of their error, who imagine, that the acid taſte of vinegar ariſes from the pungency, or ſharp, ſenſation, which theſe eels are ſuppoſed to excite on our tongues, by their pointed tails; for, were this the caſe, many ſorts of vinegar would be taſteleſs, becauſe none of the eels are to be found in them; and in winter time, vinegar would become vapid, or loſe it's ſourneſs, becauſe theſe minute eels are killed by cold or froſt.

I was deſirous to obſerve the effect of crabs' eyes being infuſed in vinegar, it being ſaid that they abſorb or take away its ſourneſs, and I concluded that this muſt be performed by the acute ſalts before mentioned being altered in figure, or rendered more ſoft or flexible, ſo as to loſe their pungency on the tongue. I took therefore, ſome new glaſſes, and after mixing in them vinegar with crabs' eyes broken in ſmall pieces, I found, that the long pointed ſalts I have before deſcribed, were altered to a kind of oblong quadrilateral figure riſing in the middle in form of a pyramid, ſimilar to a diamond when poliſhed; theſe are repreſented in *fig.* 10, at P, others were exactly ſquare, as at Q, and others of the ſhape repreſented at R. But it is to be noted, that theſe particles bore no proportion in point of ſize to the ſaline particles in common vinegar, for theſe laſt were drawn from much deeper magnifiers, without the help of which, I could not have diſcovered their ſhapes. And, what I particularly wondered at was, that theſe ſaline particles were almoſt all of the ſame ſize, which I never obſerved in any other ſpecies of ſalts. After the efferveſcence produced by the mixture of the vinegar and crabs' eyes was ſubſided, I drank about a third part of a thimble full of the vinegar, and found that it had no acid taſte, but a bitterneſs, ſo diſguſting, as almoſt to occaſion a nauſea or ſickneſs.

I have alſo pounded white chalk and mixed it with vinegar, and I found that it produced the ſame efferveſcence as the crabs' eyes, and the ſame change of figure in the ſaline particles, and that it alſo took away all the acid taſte of the vinegar.

OF THE SCORPION.

THE Directors of the Eaſt India Company in Delft, having ſent to me a living Indian Scorpion, I put it into a long and wide glaſs tube, ſtopped at the ends with cork, though not quite cloſe; and I preſumed that, on account of the coldneſs of the glaſs, the Scorpion would place itſelf on the cork, and ſo be preſerved longer alive: and I occaſionally put it into a thinner glaſs tube, in order, as far as I was able, to examine it by the microſcope.

I firſt made my obſervations on its legs, the fifth joint of which, from the body, being very tranſparent, I there plainly perceived the blood running in an artery towards the extremity of the foot; which artery, I judged to be the ſize of an hair of ones head and cloſe beſide it, the blood was returning in a vein of the ſame thickneſs. Theſe two veſſels I deemed to be the principal blood-veſſels in that limb, and, though I was well aſſured, that there were many ſmall branches through which the blood was conveyed out of the artery into the vein, and thus the circulation was compleated, yet I could not get a ſight of thoſe minute veſſels.

The blood of this creature not being of a red colour, it may be ranked among thoſe animals, which the antients named exſangues, or bloodleſs.

I ſaw that this Scorpion had two black eyes; placed, not at the extremity of the head, as we obſerve in many ſmall animals, by which they diſcover objects on both ſides of them; but theſe two eyes ſtood about the eighth part of an inch towards the back

part of its head, and ſeemed deſigned for the view of objects upwards. And I diſcovered, on each ſide of the head, three other eyes, only an eighth part the ſize of the before mentioned ones, placed in regular order beſide each other, ſo that theſe creatures are provided with eight eyes; and, as the two eyes on the top of the head are only fitted to look upwards, ſo, theſe eyes placed on the ſides are calculated to ſupply the defect of the former ones. And herein we ſee, with how much perfection and provident foreſight, every creature, however diſguſting it may be to us, is formed by Nature; and that none of ſuch creatures have ever proceeded from corruption, as ſome men have imagined, but have been produced by their like ever ſince the Creation.

I put two living flies into the glaſs with this Scorpion, in order to ſee whether it would ſeize them as its prey; but they appeared not at all frightened at the Scorpion, even ſitting upon its body, and the Scorpion was equally indifferent, and did not move itſelf on account of the flies. I afterwards put a ſmall lizard, newt or eft; and likewiſe a ſpider and a fly at the ſame time into the glaſs with the Scorpion; but it appeared equally indifferent to them all; and after I had kept it by me almoſt three months, in which time it had not taken any food, it died.

As ſoon as I perceived that the Scorpion was dead, I took a pair of ſmall forceps, and laid hold on that part in which I was perſuaded the poiſon was depoſited, and brought the ſting before the microſcope; then, by a little compreſſion of the forceps, I cauſed the poiſonous matter to iſſue forth, which might be thought to be emitted at the very extremity of the ſting, but upon examining the ſting by the microſcope, I found that on each ſide of it, near the point, was a ſmall aperture.

I have cauſed a drawing to be made of this Scorpion, in order to explain the nature of its ſting.

Plate V. *fig.* 11, repreſents the Scorpion itſelf, and at A, is the ſting, which the animal, whether in motion or at reſt, always

carries with its tail bent, or turned inwards, in order, moſt probably, to preſerve the ſting from any injury it might ſuſtain by the blunting of the point, or otherwiſe.

Fig. 12, F G H I, repreſents the ſting, as ſeen through the microſcope, and, between the letters G and H, may be ſeen the aperture which the ſting has, on one ſide; and *fig.* 13, K L M N, repreſents the other ſide of the ſting where the ſame aperture is to be obſerved between the letters L M.

It muſt here be noted, that the prominent part which is ſeen in *figs.* 12 and 13, at letter X, is not to be taken for a ſecond ſting, for in my opinion it ſerves only as a baſe or ſupport, to be fixed on the ſkin, in order that by its help, the ſting may be thruſt in with greater force.

Upon reflecting frequently on the make of this ſting, I conſidered with myſelf, that, if the above mentioned aperture had been at the very extremity, the ſting could not ſo eaſily have been made to pierce the ſkin: I alſo thought, that the Scorpion has not power to expel the poiſon, but that when the ſting enters the fleſh, then the ſides of the oblong cavity in it (which is ſeen in the *figs.* 12 and 13, between the letters G H and L M) are, by the preſſure on the ſting in its entrance (in regard the inner parts of this cavity are of a ſoft and yielding nature) forced inwards, and by that means the poiſon within the ſting is driven out. Now, if the Scorpion had power to eject its venom, I imagine that it would not ſtrike at any object whatever with its ſting, without at the ſame time emitting ſome of the venom; but as this is not obſerved to be the caſe, we muſt conclude, that the poiſon is kept within the ſting, until, by the force applied in piercing the ſkin or fleſh, the poiſon is driven out, and there it will exert its full force upon the juices of the wounded part.

The liquid matter, or poiſon which I before mentioned to have extracted from the ſting by preſſure (though it was in a very ſmall quantity) I put into a clean glaſs, which I prepared on

purpoſe, in order, if poſſible, to diſcover the ſaline particles contained in it, which alone, as it ſeems probable, do render this liquid poiſonous in ſo great a degree; but, with all my attention, I could not perceive any thing in it particularly worthy of noting.

This liquid, being in a very ſmall quantity, and alſo being ſpread very thin, in a ſhort time, all the moiſture of it was evaporated, leaving a kind of thick gummy matter, mixed with various different particles, to which I could not aſſign any particular figure. Hereupon, I, without loſs of time, made a puncture on my finger with a needle, and applied a ſmall portion of the blood which iſſued from the part, to this poiſonous ſubſtance, in order to ſee, whether the blood would undergo any alteration by the mixture. But, nothing of that kind appeared, for I could not diſcern any difference between the blood which was placed on the poiſon, and that which lay near it.

The next morning, I diſſected the tail of this Scorpion, and, from each joint, I took out two fleſhy muſcles, of a very white colour, each of which was compoſed of a great number of very ſmall oblong particles, terminating at the extremity of the muſcl where it grew ſmaller, thus forming the tendon: on one of theſe muſcles was a kind of veſſel, ſhaped in the middle like a bladder, and this, I concluded, was deſtined to convey the poiſon to the extremity of the tail. Theſe fleſhy muſcles were furniſhed with annular parts, or rings, ſerving to extend and contract the muſcle.

Thoſe eyes which were ſituated on the upper part of the head, I placed before the microſcope, whereby I ſaw how perfectly the tunica cornea, or horney coat of the eye was formed; for through it I could ſee all the ſurrounding objects (though wonderfully diminiſhed) ſo diſtinctly, that I could not contemplate the ſpectacle without admiration; but this pleaſing ſight was not of long continuance, for the tunica cornea ſoon dried and ſhrivelled up.

Upon opening the belley, I could not form any judgment of the inteſtines, by reaſon that they had begun to decay, except that I

found twelve eggs, each about the ſize of a grain of millet, of a yellow colour, and in ſhape not unlike a lemon.

In the fore part of the head, and juſt in front of the mouth, I obſerved two teeth, each fixed on a ſhort joint, and they are uſed, as I imagine, by the Scorpion, to grind its food, before it is taken into the mouth. Theſe I ſeparated from the head, and found each to conſiſt of a three-fold tooth, one of which was ſo made, as to fit exactly the cavity between the two oppoſite ones. And, to ſhew the ſtrength of theſe teeth, I cauſed a drawing to be made of one of them. *Fig.* 14, O P Q R, is this tooth, or more properly this three-fold tooth, and on it, at P, are to be ſeen ſome hairs; the legs of this creature are alſo covered with hairs.

I alſo placed before the microſcope one of the claws, which are like thoſe of crabs or lobſters, and in *fig.* 11, are to be ſeen at C or D. And I cauſed a drawing of this claw to be made, in order to ſhew the curious formation of it. *Fig.* 15, S T, is the claw, magnified, and on it are plainly to be ſeen a great number of teeth or notches, like thoſe of a ſaw, ſome of them larger than others, and which ſaw-like teeth, I doubt not are ſo formed for enabling the Scorpion firmly to hold ſuch ſmall living creatures as it catches for its prey.

Seeing now, the wonderful make of this animal, though to us it is ſo deteſtible, and indeed ſo noxious; and, conſidering the perfect wiſdom requiſite for the contrivance of its ſeveral parts, we have ſurely ten thouſand times more reaſon to believe that its origin is derived from thoſe which were created at the Beginning, than to adhere to the chimæras and errors of the ancients, ſome of whom have tranſmitted to us in their writings, the notion, that Scorpions are not produced by generation, but from the great heat of the ſun; others, that they are bred from putrefaction in the bodies of crocodiles; and others again, that they are generated in rotten wood, and ſuch like fictions.

ADDITION, BY THE TRANSLATOR.

It may not be unacceptable to the Reader, to ſubjoin a quotation from Dr. Mead's celebrated Eſſay on Poiſons, and the rather, as the ſentiments of our Author, in regard to the nature of the Scorpion's poiſon, are exactly ſimilar to thoſe of the Doctor's, when treating of that emitted from the Viper's fangs; which animal, being much larger than the Scorpion, might afford Dr. Mead a better opportunity of inveſtigating the nature of this ſubſtance, than Mr. Leeuwenhoek could have, in the very ſmall quantity which he collected from the Scorpion's ſting: and, as we ſee that the operations of Nature are performed with the greateſt uniformity in caſes which are analogous, it may fairly be concluded, that what Dr. Mead has ſaid, reſpecting the Viper's venom, may be applied to that of the Scorpion, and of more minute noxious animals.

Dr. Mead expreſſes himſelf on this ſubject, in the following words:

'This venomous juice itſelf is of ſo inconſiderable a quantity, that it is no 'more than one good drop that does the execution. And for this reaſon, 'authors have contented themſelves with trials of the bite upon ſeveral animals, 'never eſſaying to examine the texture and make of the liquor itſelf: for 'which purpoſe, I have oftentimes, by holding a Viper advantageouſly, and 'enraging it till it ſtruck out its teeth, made it bite upon ſomewhat ſolid, ſo as 'to void its poiſon; which, carefully putting upon a glaſs plate, I have with a 'microſcope, as nicely as I could, viewed its parts and compoſition.

'Upon the firſt ſight, I could diſcover nothing, but a parcel of ſmall ſalts 'nimbly floating in the liquor; but in a very ſhort time, the appearance was 'changed, and theſe ſaline particles were now ſhot out, as it were, into cryſtals 'of an incredible tenuity and ſharpneſs, with ſomething like knots here and 'there, from which they ſeemed to proceed: ſo that the whole texture did in 'a manner repreſent a ſpider's web, though infinitely finer, and more minute; 'and yet withal, ſo rigid where theſe pellucid ſpicula, or darts, that they remain-'ed unaltered upon my glaſs for ſeveral months.*

'I have tried ſeveral ways to find out, if I could, under what tribe of ſalts 'theſe cryſtals are to be ranged, and to diſcover what alterations they make in

* A repreſentation of this, taken from Dr. Mead's work, is given in Plate V. *fig.* 16.

'the blood: and, not without ſome difficulty, by reaſon of the minute quantity 'of the liquor, and the hazard of experiments of this kind, ſome curious friends, 'and myſelf together, made the following obſervations:

'About half an ounce of human blood received into a warm glaſs, in which 'were five or ſix grains of the viperine poiſon newly ejected, was not viſibly 'altered either in colour or conſiſtence: it then was, and remained undiſtin-'guiſhable from the ſame blood, taken into another glaſs in which was no 'poiſon at all.

'Theſe portions of blood were ſeverally mixed with acids and alkalis: the 'empoiſoned blood was, after ſuch mixtures, of the ſame colour and conſiſt-'ence as the other.

'Spirit of nitre, ſpirit of ſalt, and juice of lemons, ſeverally poured upon 'the ſanies itſelf, produced neither fermentation, nor any change of colour.

'Salt of tartar run per deliquium, and the ſimple ſpirit of harſhorn, dropped 'upon the venom, neither altered its colour, nor raiſed any ebullition.

'Syrup of violets mixed with the poiſon did not change its colour either to 'red or green.

'The tincture of heliotropium, that is, blue paper, was not altered by the 'ſanies ejected upon it; and this, drying, ſtill retained its yellowiſh colour.

'We cauſed ſeveral animals, dogs, cats and pigeons, to be bit by an enraged 'Viper; which generally died, ſome in a longer, others in a ſhorter ſpace of 'time. But we conſtantly obſerved, that they all, immediately upon the bite, 'ſhewed with ſigns of acute pain, marks of their life being affected, by 'ſickneſs, faintings, convulſions, &c.

'The head of a large Viper lay three hours after it was cut off; it was per-'fectly flaccid and without motion. A pigeon, wounded upon the breaſt with 'the fangs of this head, was preſently convulſed, &c. as from the bite of the 'animal, and died in ſeven hours.

'We contrived a ſharp ſteel needle to be made, crooked, in ſhape not un-'like to the Viper's tooth, with a ſulcus or hollow on the convex part, not far 'from the point: into this, we put a drop of the venom, and with it wounded 'the noſe of a young dog. It produced the uſual diſorders of vomiting, purg-'ing, &c. but in a leſs degree, and the dog recovered. It was remarkable, 'that upon making the wound the dog cried but little, till the poiſon came 'into it; but then he howled, &c. in the ſame manner as if bit by the viper 'itſelf. But a pigeon pricked in the fleſhy part of the breaſt, by the ſame 'poiſoned needle, ſuffered as from the bite, and died in about eight hours.

'We reſolved to end out poiſon-inquiries by taſting the venomous liquor. 'Accordingly, having diluted a quantity of it with a very little warm water, 'ſeveral of us ventured to put ſome of it upon the tip of our tongues. We all 'agreed, that it taſted very ſharp and fiery, as if the tongue had been ſtruck 'through with ſomething ſcalding or burning. This ſenſation went not off in 'two or three hours, and one gentleman, who would not be ſatisfied without 'trying a large drop undiluted, found his tongue ſwelled, with a little inflam-'mation, and the ſoreneſs laſted two days; but neither his, nor our boldneſs, 'was attended with any ill conſequence.

'This is no objection to the hurtful quality of this juice: for, as ſome chy-'mical liquors ferment with others of a certain kind only, ſo theſe poiſonous 'ſalts may affect one fluid of the body, and not another; it is ſufficient to the 'preſent purpoſe to ſay, that the ſaline ſpicula are broken and diſſolved in the 'mouth by the clammy ſalival humour: and if any of them ſhould paſs thence 'into the ſtomach and inteſtines, the balſam of the bile will be an antidote 'there, powerful enough to overcome their force.

'Theſe experiments upon the Viper poiſon and the blood, are a ſufficient 'confirmation, that the nervous liquor only is affected by this venom; and at 'the ſame time afford a convincing proof, how much thoſe ſcanty principles of 'our chymiſts, acid and alkali, fall ſhort in explaining the actions of natural 'bodies; ſince neither of theſe ſalts could in any way be found to affect the 'viperine venom.'

Mechanical Account of Poiſons, p. 14, & ſeq. Ed. 1747.

The Doctor's Eſſay on the Nervous Fluid and the manner in which it is affected by animal poiſons, is too long to inſert in this place, but the Reader will find it in the Introduction to the work from which the preceding paſſage is taken; that is to ſay, in the later editions, for it is not to be found in the firſt, printed 1702.

Of the Oak gall, or Gall-nut; that it is not a fruit, but an excreſcence produced on the leaves of the oak, by means of an inſect; the manner of its formation particularly deſcribed. A ſimilar excreſcence produced in like manner on the Thiſtle.*

WHILE I was employed in the ſummer ſeaſon, to collect acorns from the oak, in order to examine the beginning plant in that ſeed, I ſaw with ſurprize, that the gall-nuts were produced upon the leaves of the trees. This ſeemed the more extraordinary, becauſe I had ſuppoſed that they were the fruit of the tree, but now I found that they were occaſionally, or accidently produced on the leaves of the oak. I was convinced of this, partly, becauſe I ſaw but a few leaves here and there with gall-nuts on them, (in ſome of which I found four, five, and even ſix galls) and in others I could not find a ſingle one; and in the next place, becauſe I ſaw, that theſe galls were formed upon the large fibres, or veſſels in the leaves, which were burſt or broken, in the places where the galls were formed; ſo that I concluded that ſome inſect had wounded or gnawed thoſe veſſels, and that the juices of the tree, flowing out of the wounded part, had extended themſelves in globules and veſſels, and thus, at length cauſed the formation of the gall-nut.

* This is a literal tranſlation of the Dutch word *Galnoot*, uſed by the Author; in the Latin tranſlation it is *Galla*, which Ainſworth renders 'a fruit called gall, or oak-apple;' but this is a miſtake, for the oak-apple is not the gall, nor is it formed on the leaves of the tree, but at the ends of the ſmall twigs; and it is produced, not by a ſingle inſect, but by a great number collected together, and thoſe of a different ſpecies from the inſect found

On my return home, I examined theſe gall-nuts more accurately, and found that each of them had a cavity in the middle, wherein lay a living white worm, which had very little motion: it was thick, in proportion to its length, and lay bent in a circular form, the body of it conſiſting of thirteen or fourteen rings, as we ſee ſilk-worms and caterpillars, and theſe covered with pointed hairs.

It ſeemed to me worthy of obſervation, that, from this time, I obſerved theſe worms, or maggots, continue alive to the end of December; and that, in gall-nuts which I had gathered in the ſummer, and which were ſo dried, that I thought they were ſhrunk to half their former ſize; whereupon I concluded that the worms, for want of ſufficient nouriſhment, had not arrived at their full growth, ſo as to be changed into flies, and had only been ſupplied with food ſufficient to keep them alive. But, when they had grown to be ſomewhat larger than a great pin's head, then I ſaw the eyes beginning to be formed, which were of a black colour.

After this, I went occaſionally into the wood at the Hague, in order to purſue my ſpeculations, and obſerved that theſe worms were changing into flies; for, I not only could ſee their eyes perfectly formed, but I alſo could diſcern plainly their horns and feet, and the hind part of their bodies. This inſect then lay without any motion that I could perceive, with its feet, ſix in number, and its two horns lying in regular order cloſe to its body, in like manner as we ſee in the aurelia of the ſilk worm, before it comes out of its ſhell, or covering, but in this animalcule I did not then obſerve any ſuch caſe or covering; but only the ſhape of a ſmall fly without wings, the hind part of its body of a round form and of a ſhining black colour, and which in a ſhort time was provided with two larger and two ſmaller wings: and I afterwards found that theſe aurelias had a thin covering, which encloſed the body, but not the feet.

From theſe my obſervations, I concluded, that theſe animalcules

were thus produced, namely, by the before-mentioned kind of fly, laying its eggs on the leaves of the oak, where, when the young maggot is hatched, it bites or pierces the veſſels of the leaf, ſo that the juices flow out, and are hardened into globules, ſpreading themſelves, at the ſame time, in a circular form like veſſels, and thus produce what is called the gall-nut, and which juices, while hardening, do incloſe the maggot in the middle.

This newly-formed gall-nut ſupplies the animal with food, for it eats away the ſubſtance of the nut by little and little, round about itſelf, whence proceeds the cavity we find in the middle of theſe galls, and which cavity grows larger, as the animal increaſes in ſize. And it ſeems to me, that unleſs ſome of the large veſſels in the leaves were injured or perforated by one of the maggots I have deſcribed, there could not be any gall-nut formed, for in every nut which I opened, I conſtantly found a maggot (though in an hundred ſuch nuts, I found but two which contained more than one) and this, though one gall-nut was ſixty times the ſize of another,

It is however to be noted, that the wounding or biting the large veſſels in the leaves, does not conſtantly produce a gall-nut; for this is only formed, where a ſufficient quantity of the juices iſſues from the opened veſſels; to this alſo, the heat contributes much, by condenſing or thickening the juice; and hereupon it is my opinion, that where theſe veſſels are opened in the morning, galls will more eaſily be formed than when it happens in the evening; for I ſaw on thoſe leaves on which were gall-nuts, and alſo on thoſe where none were to be ſeen, the leaves and veſſels much eaten into, and the veſſels pierced through, and yet, not the leaſt appearance of the formation of a nut on the place. Farther, I concluded, that many of theſe maggots get their ſuſtenance from the leaves without piercing the large veſſels, for in many places I ſaw the leaves eaten away and in holes.

In further proſecuting my inquiries on this ſubject, I found

that the beſt ſort of gall-nuts which are uſed in this country, are brought from Aleppo. Hereupon I conſulted Tavernier's Travels, to ſee what he ſays on this ſubject; and I found, that in his third book, when ſpeaking of his journey to Aleppo, he ſays, 'the 'hills are covered with oaks bearing the gall-nut, and ſome 'of them, beſides gall-nuts, alſo produce acorns.' But, after the preceeding obſervations, we are not to wonder, that the ſame oak will produce both galls and acorns, ſince nothing more is wanting for the production of a gall-nut, than ſuch a fly as I have mentioned, from the eggs of which, worms ſhall proceed, which feed upon the leaves of the oak.

To ſatisfy myſelf more fully in this particular, I examined ſeveral of thoſe gall-nuts which are imported to us, and are much uſed by dyers; and in ſome of them I found a dead fly, of the ſame ſhape with thoſe found in the galls of this country, and in others, only a cavity in the middle, with a round hole reaching from that cavity to the ſurface of the nut, and in the cavity a kind of duſt, which I imagined to have been the excrements of the worm while it was in the nut. And I found upon farther proſecuting my obſervations on the galls which I gathered from the trees here, that not only the maggot is able to gnaw the ſubſtance of the nut; but alſo, that the fly has power to perforate it, to open a paſſage for itſelf though I do not think that the fly uſes the ſubſtance of the nut for food.

In others of theſe Aleppo galls, I ſaw no appearance of any living creature having been incloſed; the reaſon of which I concluded to be, firſt, the maggot in our gall-nut, even when of its perfect ſize, is very tender, and cruſhed with the leaſt touch, and contains nothing in it, but a whitiſh fluid ſubſtance, ſo that if a maggot happens to die in the nut, whether from the juices being too acrid, or the nut too hard, in ſuch caſe, the ſubſtance of the worm may ſo dry away, as to leave no traces behind it. In the next place, a maggot, when grown to a conſiderable ſize,

may pierce a large veſſel in the leaf, and afterwards ſhift itſelf to another place, and out of the large veſſel ſo wounded, a gall-nut may be produced without any maggot in it. The gall-nuts which are formed without any inſects in them, are generally the heavieſt, by reaſon that they have not any cavity made in their inſides.

With regard to my preceding obſervations on this ſpecies of fly, I was the more confirmed in my opinion, upon recollection of what I have obſerved of the like kind in divers trees, and particularly the willow; on the leaves of which I have ſeen certain green tubercles or ſwellings, on opening which I have found animalcules within them, ſome of which were alive, and others dead; all which I doubted not were produced by maggots hatched from the eggs of the flies of the ſame ſpecies as thoſe which I had found in ſuch tumours or ſwellings. For it is with me an eſtabliſhed principle, that no living animal, whether worm, fly, gnat, or mite, can be produced from the mere juice or leaf of any tree or plant, nor from corrupted or decayed ſubſtances.

I have cauſed a drawing to be made of theſe galls, as they grow or are produced on the leaves; and in Plate V. *fig.* 17, A B C D, is repreſented an oak leaf, with that ſide upwards, which, when on the tree is undermoſt; for I never ſaw any of theſe galls on the upper ſide of the leaf; the reaſon of which I take to be, that if the maggot was placed on the upper ſide, and expoſed to the ſun's heat but for a ſhort time, it would, by reaſon of its ſmallneſs, be dried up and periſh. On this leaf are ſeen two large galls, and two ſmaller ones, at the letters E, F, G, H.

Fig. 18, 18, exhibit a gall-nut cut in half, wherein, at N, N, appears the cavity, in which the maggot lay; ſome of theſe maggots, of different ſizes, are ſhewn at I, K, L, M.

Fig. 19, ſhews one half of a gall-nut, with the fly in it, which has opened to itſelf a paſſage from the cavity as far as the ſurface of the nut, and at *fig.* 20, is the other half, exhibiting the cavity in

the center, formed by the maggot, and the perforation to the circumference made by the fly.

Fig. 21, is the fly bred in this gall-nut, whoſe body is not quite ſo large as repreſented in this figure, but the wings are of the ſame ſize as they appear here.

After theſe obſervations, in the month of January, I again went in ſearch of gall-nuts, upon the leaves of the young oaks, and thoſe which hung near the ground; and I found a great number of them, although the leaves were very much dried: in many of theſe galls I ſaw the perforation through which the fly had iſſued; in others of them I found living flies; and in others, living maggots.

Some of theſe galls I placed in my cloſet, and opened them at different intervals of time, and I always found either the maggot in them alive, or a hole, through which the fly had iſſued: ten of theſe I kept till the end of April, and upon opening them, I found them all perforated with holes, and the flies which had iſſued from them, lying dead.

While I am on this ſubject, I can not forbear to mention, that in the autumn there were brought to me a parcel of roundiſh ſubſtances, which were gathered from thiſtles, and therefore, called thiſtle-nuts. Many of our countrymen carry theſe nuts in their pockets, under a notion that while they wear them, they ſhall be free from the diſorder called the piles, particularly if every year, they throw away the old nuts and procure freſh ones (which, it is ſaid, do not grow in our province). And ſome ſay, that there is a maggot in theſe nuts, and that while it lives, the before mentioned virtue remains in the nut, but upon its dying the virtue is loſt.

As ſoon as I ſaw theſe ſuppoſed nuts, I concluded that they were produced, as I might ſay, by accident; and that their virtue againſt the piles was a mere imagination. And upon examining the nuts, I found that there was not one of them which had not one,

two, three, four, and ſome as many as ſeven or eight cavities in it, each cavity containing a ſhort, white aurelia, or chryſalis, formed of many joints like rings; theſe aurelias were almoſt all alive, and I judged them to have been produced from maggots, the offspring of ſome fly or ſuch like inſect, which had laid its egg on the thiſtle; and that thoſe maggots having pierced the veſſels of the thiſtle, while in the flouriſhing time of its growth, had occaſioned a copious effuſion of juices, by means of which a tumor or ſwelling had been formed upon the thiſtle, which had incloſed the maggot, and formed a ſolid ſubſtance round it. And upon further proſecuting this ſubject, to elucidate my own poſition that theſe nuts had been produced by means of maggots, I opened ſeveral of them at different times in the ſucceeding winter, preſerving the aurelias; and at length, towards the end of the April following, they produced a ſpecies of black flies, different from any I had before ſeen, for the hind part of their bodies terminated in a point, forming a kind of ſheath, wherein was contained a ſmall ſting.

I thought it would not be amiſs, to exhibit to the view, the ſhape and make of theſe nuts, in order to ſhew the ſizes of them and of the cavities they contain; and alſo how far, fancy and imagination will go with ſome people.

Plate V. *fig.* 22, 23, 24, repreſent three of theſe thiſtle-nuts dried, and of different ſizes.

Fig. 25, is one of the ſame nuts, cut open on the ſide, where may be ſeen two cavities, one of them, at A, containing an aurelia.

Fig. 26, is the fly produced from this aurelia.

Fig. 27, is a thiſtle-nut cut acroſs, ſhewing ſeven cavities, wherein the aurelia had lain.

END OF THE FIRST PART.

INTRODUCTION to the SECOND PART.

AS I have entitled this Tranſlation, The diſcoveries of the Author in many of the Works of *Nature*, a term uſed by himſelf) I ſhall take the liberty to lay before the Reader a few words, reſpecting the idea we ought to annex to that expreſſion.

By the word Nature, here uſed, I underſtand that unſeen power whereby different parts of Matter are brought together, and, by their various combinations and modifications, produce thoſe bodies or ſubſtances which we obſerve on this terraqueous globe. Matter, is that *Something*, of which Bodies are compoſed, and I call it Something, becauſe it primary or original particles are ſo minute as to be entirely undiſcernible by us; and it is not until they are combined or collected in larger portions that they become objects of our ſenſes. This is capable of demonſtration many ways: for example, Earth, which, in itſelf, has little either of taſte or ſmell, produces herbs, flowers, and fruits, poſſeſſing an endleſs variety of taſtes and odours; and not only ſo, but of natures entirely different from each other, the ſame ſpot of earth which produces wholeſome herbs for our tables, bringing forth alſo the moſt noxious plants, according to the quality of the ſeed or plant committed to it: and yet, we cannot trace theſe various taſtes and odours, nor theſe wholeſome and noxious properties, in plants, to any other original than the ſame common parent Earth, aided by ſuch ſupplies as they receive from the other *elements. Herbs, taken into the ſtomachs of animals, are converted

* Water, it is well known, is eſſential to the growth of plants, neither will they vegetate without a ſupply of Air, a fluid eight hundred times lighter than water; and, it is the opinion of Sir Iſaac Newton, that Light, which is beyond all conception more rare and ſubtile than air, does enter into the compoſition of Bodies.

into the fleſhy parts of their bodies, and even compoſe the ſolid ſubſtances of the bones and teeth: and all theſe vegetable and animal ſubſtances do, by putrefaction, return to the general maſs of Matter from which they were firſt formed, and enter into the compoſition of new Bodies. Again, water evaporates, or is carried up into the atmoſphere, in particles ſo ſmall as to be inviſible to us; and even mercury or quickſilver, the heavieſt of all fluids, upon the application of a moderate degree of heat, flies off in vapour, and, unleſs confined by ſome ſolid body, ſuch as a chemiſt's retort, wholly diſappears. Arguing then, from theſe appearances, we muſt conclude, that the elementary or original particles of Matter, are not, as ſuch, diſcoverable by us. And, as far as ocular examination can reach, Mr. Leeuwenhoek has given it as his opinion, that, had he been able, by the help of glaſſes, to have diſcerned objects, millions of times ſmaller than thoſe his microſcopes diſcovered, he could not have traced Bodies to their original component particles.

Some Philoſophers have ſpent much time in arguing on the infinite diviſibility of Matter, and in propoſing ſtrange * theories reſpecting its inherent properties. But herein, they ſeem to have exerciſed their wits, without much improving their underſtandings; for ſurely, it is of no utility to propound queſtions, which cannot poſſibly be brought to the teſt of experiment. In oppoſition to theſe vain ſpeculations, how wiſe, and, at the ſame time, how modeſt, are the words of Sir Iſaac Newton: † "It ſeems probable to me, that God in the Be-
" ginning, formed Matter, in ſolid, maſſy, hard, impenetrable, move-
" able particles, of ſuch ſizes and figures, and with ſuch other proper-
" ties, and in ſuch proportion to Space, as moſt conduced to the end for

* Such as that of ſuppoſing the coheſion of bodies to be cauſed by their particles being formed with little hooks; and, that repulſion proceeds from other particles being made like hoops rolled up, and afterwards expanding themſelves.

† Newton's Opticks, Qu. 31, near the end.

" which he formed them; and, that theſe primitive particles being
" Solids, are incomparably harder than any porous bodies compounded
" of them, even ſo very hard as never to wear or break in pieces;
" no ordinary power being able to divide, what God himſelf made one
" in the firſt Creation. While the particles continue entire, they may
" compoſe Bodies of one and the ſame nature and texture in all ages;
" but, ſhould they wear away or break in peices, the nature of things
" depending on them would be changed. Water and Earth, com-
" poſed of old worn particles, and fragments of particles, would not
" be of the ſame nature and texture now, with water and earth com-
" poſed of entire particles in the Beginning. And therefore, that
" Nature may be laſting, the changes of corporeal things are to be
" placed only in the various ſeparations and new aſſociations and mo-
" tions of theſe permanent particles; compound bodies being apt to
" break, not in the midſt of ſolid particles, but where thoſe particles
" are laid together, and only touch in a few points." This ſeems to be the *ne plus ultra*, or utmoſt extent of human ſagacity, terminating in a concluſion, worthy of that great Philoſopher and good Man. In conformity to which, I think we may ſay, that the particles of Matter are not infinitely, but indefinitely ſmall, or, in other words, ſo minute as to be ſingly, inviſible to us, though collectively, they are the daily objects of our ſenſes. It now remains to conſider the properties of Matter, or, the means by which its particles are brought into action.

The Honourable Mr. Boyle has written an Eſſay on this ſubject, wherein he refutes the error of the ancient heathen Philoſophers, and their followers among the moderns, the Schoolmen, who figured to themſelves, an active, intelligent Being, which they called Nature; ſubordinate indeed to the Deity, but yet, preſiding over the mundane Syſtem, and directing its operations. He ſhews, in a variety of inſtances, that the ſuppoſition of ſuch a Being, is inſufficient to ſolve

the different phænomena in the ſyſtem, and, that it detracts from the honour of the Author and Governor of the World: And he gives us his opinion on the ſubject, in theſe words: * "Since the preſent is a "philoſophical enquiry only, we ſhall only, at preſent, conſult the "light of reaſon in the formation of the World, which might proba- "bly be after the following manner. The great and wiſe Author of "things, firſt forming the univerſal undiſtinguiſhed Matter, put its "ſeveral parts into various motions, by which they muſt needs be di- "vided into innumerous particles of different bulks, figures, and ſitu- "ations; guiding and over-ruling the motions of thoſe parts, by his "wiſdom and power, ſo as to diſpoſe them into that beautiful and "orderly frame we call the World; ſome being ſo contrived, as to "form ſeeds, or the ſeminal principles of Plants and Animals. Be- "ſides, he ſettled ſuch laws or rules of local motion, amongſt the parts "of Matter, that, by his ordinary concourſe, the parts of the Univerſe "once compleated, ſhould continue the œconomy of the Univerſe, and "propagate the ſpecies of living creatures." And again, he ſays, "If we ſuppoſe the univerſal laws of motion to be eſtabliſhed, and "that, by their conventions, the ſeminal principles of various things "were contrived, by the local motion of Matter, ſkilfully guided at the "beginning, and that God's ordinary and general concourſe, contri- "buted to perfect the Univerſe, and continue it ſo, there is no need of "any diſtinct powerful intelligent Being to aſſiſt him, as Nature is "repreſented; ſince the Phænomena which occur, will flow from the "mere fabrick and conſtitution of the World."

The learned Dr. Mead has a paſſage on this ſubject of Nature, when applied to animated bodies, which I the rather quote, as it contains a reproof to thoſe viſionary Philoſophers I have mentioned.

† "Whereas the Word *Nature*, is made uſe of by Phyſicians, in

* Enquiry into the received notion of Nature.

† Mead on the Small Pox, Chap. II.

" the cure of all diſeaſes, I will here, once for all, plainly declare my
" ſentiments of what we ought to underſtand by that word. That
" there is ſomething within us, which perceives, thinks, and reaſons,
" is manifeſt beyond contradiction: And yet, the nature of that
" *ſomething*, cannot be fully and perfectly comprehended in this life.
" Wherefore I ſhall reſign the diſquiſition of this point to thoſe, who,
" while they know too little of, and care leſs for, things falling under
" their ſenſes, take great pleaſure in inveſtigating thoſe things which
" human reaſon is incapable of conceiving. However, thus far the
" ſoundeſt Philoſophers agree concerning it, that it is ſomewhat in-
" corporeal. For, how can ſluggiſh Matter, which is, of itſelf, void
" of all motion, be the ſource and firſt cauſe of Thought, the moſt
" excellent of all motions? Wherefore, it is ſufficiently evident,
" that this firſt mover within us, is a ſpirit of ſome kind or other,
" entirely different and ſeparable from terreſtrial matter, and yet,
" moſt intimately united with our body."

" Moreover, to me, it ſeems probable, that this active principle, is
" not of the ſame ſort in all; that the Almighty Creator has en-
" dowed man with one ſort, and brutes with another; that the for-
" mer ſo far partakes of a divine nature, as to be able to exiſt, and
" think, after its ſeparation from the body; but that the latter is of
" ſuch an inferior order, as to periſh with the body."

" Now this matter, if I am not miſtaken, ſtands thus: Such is the
" compoſition of our fabrick, that when any thing pernicious has got
" footing within the body, the governing mind gives ſuch an impulſe
" to thoſe inſtruments of motion, the animal ſpirits, as to raiſe
" thoſe commotions in the blood and humours, which may relieve
" the whole frame from the danger in which it is involved. And
" this is done in ſo ſudden a manner, that it ſhould ſeem to be the
" effect of inſtinct, rather than voluntary motion, though it be
" effected at the command of the active principle. And, indeed, thoſe

" very motions, which are commonly called natural and vital, as " thoſe of the heart, lungs, and inteſtines, which perſevere through " the whole courſe of life, even when the will cannot be concerned " in them, as they have their beginning from the mind, ſo they are " perpetually under its direction."

Sir Iſaac Newton, in that part of his works above quoted. expreſſes himſelf as follows: " All material things ſeem to have been " compoſed of the hard and ſolid particles above mentioned, variouſly " aſſociated in the firſt Creation, by the counſel of an intelligent Agent. " For, it became him who created them, to ſet them in order. And, " if he did ſo, it is unphiloſophical to ſeek for any other origin of the " World, or to pretend, that it might ariſe out of a chaos, by the " mere laws of Nature; though, being once formed, it may continue " by thoſe laws, for many ages. For, while Comets move in very " eccentrick orbs, in all manner of poſitions, blind Fate could never " make all the Planets move one and the ſame way, in orbs concen- " trick, ſome inconſiderable irregularities excepted, which may have " ariſen from the mutual actions of Comets and Planets upon one " another, and which will be apt to increaſe, till this Syſtem wants " a reformation. Such a wonderful uniformity in the Planetary " Syſtem, muſt be allowed the effect of choice. And ſo muſt the " uniformity in the bodies of animals they having generally, a right " and a left ſide, ſhaped alike, and, on either ſide of their bodies, two " legs behind, and either two arms, or two legs, or two wings before " upon their ſhoulders; and, between their ſhoulders, a neck run- " ning down into a back bone, and a head upon it; and, in the head, " two ears, two eyes, a noſe, a mouth and a tongue, alike ſituated. " Alſo, the firſt contrivance of thoſe very artificial parts of animals, " the eyes, ears, brain, muſcles, heart, lungs, midriff, glands, larynx, " hands, wings, ſwimming bladders, natural ſpectacles, and other " organs of ſenſe and motion, and the inſtinct of brutes and inſects,

" can be the effect of nothing elſe, than the wiſdom and ſkill of a " powerful ever-living Agent, who, being in all places, is more able, " by his will, to move the bodies within his boundleſs uniform " *Senſorium, and thereby to form and reform the parts of the Uni- " verſe, than we are, by our will, to move the parts of our own " bodies."

I hope I may be permitted to add to the opinions of theſe great men, an obſervation, which, I think, muſt have occurred to them, though they have not particularly mentioned it, except Sir Iſaac Newton, in the laſt lines of the paſſage I have quoted from him. The laws of motion which, according to Mr. Boyle, were eſtabliſhed at the Beginning, and afterwards, continued, by what he calls, " the " ordinary concourſe of the Creator, " and which principles are ſtiled by Sir Iſaac Newton, " the laws of Nature," cannot have any force without the ſame exertion of power to ſupport them, by which they were at firſt created. Nor can the incorporeal mind or ſpirit, mentioned by Dr. Mead, preſerve its activity without the continued influence of the Supreme Mind. For, the caſe is not analogous to what may be ſuppoſed of a workman, conſtructing a machine, which ſhall for a length of time continue in motion, without his intervention; nor to that of a maſter, giving directions to his ſervants to perform, what they afterwards accompliſh of themſelves. For, in the one inſtance, the machine, if its firſt mover be a weight, is kept going by the law of gravity, and, if a ſpring, by the power of elaſticity, both which are entirely independent of the workman; and, in the other inſtance, the ſervant executes his maſter's commands by virtue of the powers of ſelf volition and action he poſſeſſes, independent of that maſter, though, for the time, he willingly applies thoſe powers to the accompliſhment of the taſk aſſigned to him. But, we cannot

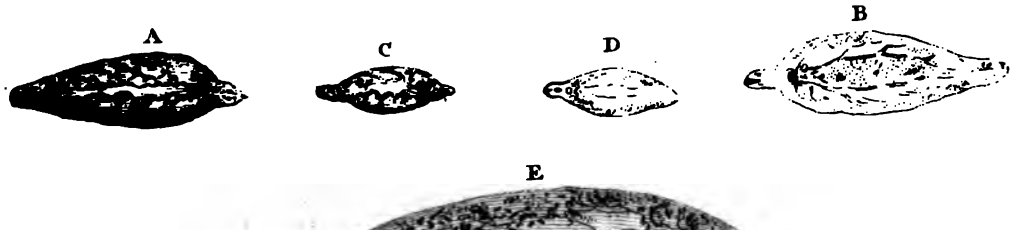
* Senſorium, means the ſeat of conſciouſneſs or perception, in animated Beings; and, when applied to the Deity, his Omnipreſence makes it to be every part of Space.

conceive any active principle to exiſt, in either Matter or Spirit, without the ſupport of the firſt Cauſe; for this would be to ſuppoſe more than one active independent Exiſtence, which Dr. Clarke has proved to be the greateſt abſurdity.* Upon the whole, when we inveſtigate this ſubject as far as our faculties will extend, we cannot do otherwiſe than reſolve all, that we call the operations of Nature, into the continual agency of the firſt Creator. And, though we are loſt in the idea of ſuch immenſe and inceſſant energy, we are equally ſo, in the contemplation of any other of the Divine Attributes, foraſmuch as finite capacities cannot comprehend Infinitude.

While we poſſeſs theſe ſentiments, and keep the idea of Nature, and the Author of Nature, connected, (which it is not eaſy for a reflecting mind to ſeparate) I cannot, for my part, but approve the † perſonifying figure, which I think more decorous than to name the Deity on every trivial occaſion: and Mr. Leeuwenhoek ſeems to have been of this opinion, for he frequently uſes the expreſſion "de voorſichtig Natuur" *i. e.* provident Nature, but when the wonders he diſcovers excite his admiration, that admiration is always directed to the Creator.

* Clarke's Demonſtration of the Being and Attributes of God.

† The Ancients pictured Nature in a female form, to denote her fruitfulneſs; and, with many breaſts, to typify the abundant proviſion made by her for her different productions.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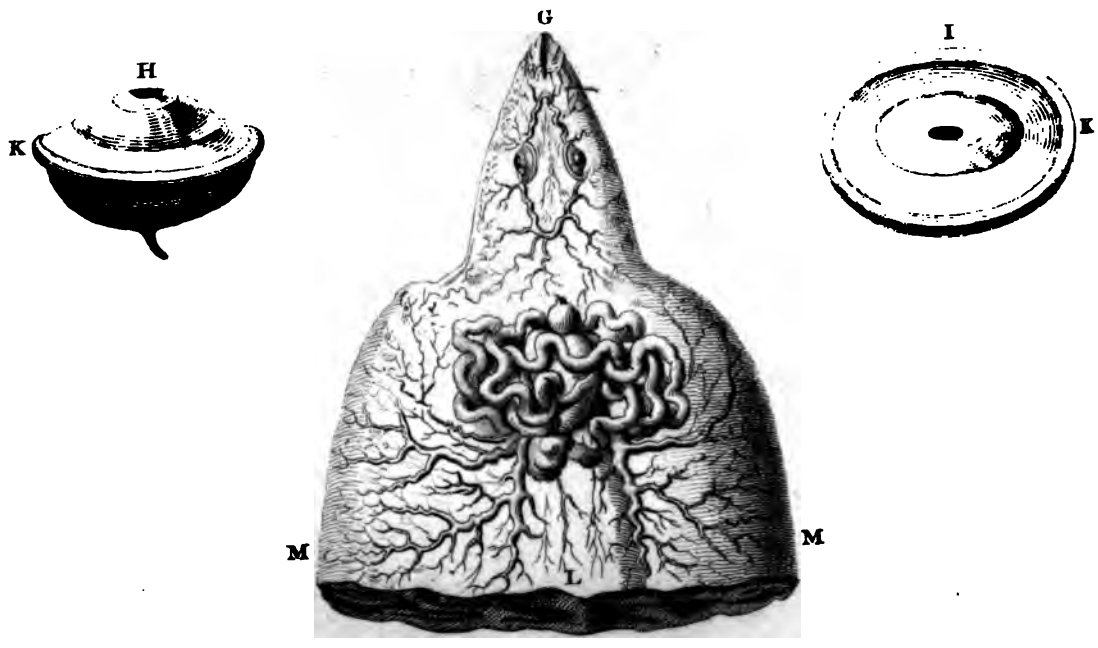
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Of an Animalcule or ſmall living creature, which is ſometimes found in the livers of Sheep and other beaſts.

To make my obſervations on this ſubject the more intelligible, I ſhall place them in the following order: Firſt, as to the ſhape and make of this animalcule; Secondly, the part of the inteſtines where it is found; Thirdly, its numbers, and the manner of its propagation; and Fourthly, how theſe creatures, and other animalcules of a ſimilar nature, by fixing themſelves in the liver and other internal parts of the body, can produce certain diſeaſes, and their fatal conſequences.

Firſt, as to the ſhape and ſize of this creature, and its ſimilitude to other known animals; it bears a near reſemblance (in miniature) to our ſole or flounder, as appears by *fig.* A, which repreſents it of the ſize it is commonly found; this figure ſhews the back or prominent ſide; and *fig.* B, the belly, or flat ſide of it. C is one of the young of the ſame ſpecies, ſhewing the back, D the belly of the ſame; E and F are figures of the ſame creature, ſomewhat magnified, and ſhewn in the poſitions before mentioned.

Theſe animals are not often ſeen alive, becauſe the diſeaſe they produce does not always ſhew itſelf by outward tokens, and the beaſt afflicted with them, ſometimes ſeems fat and in good health, and then the liver is not perhaps examined till ſome time after the beaſt is killed; and theſe creatures cannot endure cold, but if by being expoſed to it they are deprived of motion, they will revive, if the liver be held in a warm hand or put into warm water. Their motion is undulating or wriggling like that of the fiſhes before mentioned, their colour a yellowiſh brown, the belly quite flat, and

much paler coloured than the back, the ſkin rough and covered with prickles or points, and ſo tranſparent, that the bowels and veſſels may plainly be ſeen on both ſides. The head which is ſhewn conſiderably magnified, at letter G, is of a pointed form, plano-convex, that is, rounding above and flat below, the mouth projecting, open, and of an oval ſhape, nearly in faſhion like a carp. The eyes, which are pictured ſeparately at H and I, are very prominent, and ſurrounded with a cartilaginous or griſtly ring, which is ſhewn at K, and they are placed, as we ſee in many flat fiſhes, both of them on one ſide of the back, with a diviſion between them.

The heart is ſo near to the head, and the bowels ſo cloſely conjoined to the heart, that I queſtion whether there is any thing, properly to diſtinguiſh the head from the reſt of the body, which yet in moſt animals are ſeparate and diſtinct. From the heart, ariſe two veſſels ſpreading over the whole body, with a wide ſpace between them, extending almoſt the whole length of the back, as repreſented at letter L, and between theſe veſſels are many ſmaller ones, as ſhewn at M, which are ſo minute that no moiſture can be diſcovered within them. I obſerved in the larger veſſels two ſorts of juices, namely, in ſome a yellowiſh brown, and ſometimes a kind of purple; in others a pale green, both of a glutinous or ſlimy nature, and yet flowing in the veſſels even after the death of the animal, towards the heart, if held up by the tail, and back again, upon the head being raiſed.

The excretory duct, or paſſage of the bowels, is in an unuſual place, being on the right ſide of the body, cloſe under the head, for which reaſon the inteſtines are as it were, crowded together in an heap. There is a ſmall protuberance at the beginning of the bowels, which I take to be the liver, and between this and the bowels, I find in all of thoſe animalcules which I have examined, an innumerable quantity of oval particles, hundreds of which, taken together, are not equal to the ſize of a grain of ſand. They are of a pale red colour, and I take them to

be the ſpawn or eggs. Notwithſtanding my moſt diligent examination of theſe creatures, I never could diſcover any difference of ſexes; and it ſeems to me moſt probable, that they are of that ſpecies called Hermaphrodites, or every one equally prolifick; at leaſt, none has ever fallen into my hands which appeared plainly to be a male. The tail, though of the ſame texture with the reſt of the body, is much tenderer, breaking or tearing upon the ſlighteſt touch.

The parts in ſeveral animals wherein I have hitherto found theſe creatures, are only the veſſels, tubes, and channels wherein the gall is formed and collected, though moſt commonly in the liver; and here they may be ſaid to ſwarm, producing grievous ſwellings, calloſities, contorſions, and ſinuſes in the part; and cavities, which will be often found an inch and an half in diameter. In theſe parts theſe noxious animalcules are found in heaps, and the places where they lie, become hard and cartilaginous. In the ſmall gall-ducts they lie longitudinally, and ſometimes rolled or curled up together; and I believe that many perſons have hereby been led into a miſtake reſpecting the ſhape of them, deſcribing them to be oblong, round worms; but in truth, however cloſely they may be thus rolled up, they will ſpread open again, even after they are dead, upon being thrown into warm water, for then they recover their flat ſhape, but at the ſame time they become rather of a paler colour than they originally were.

Theſe creatures are commonly found in great numbers, though in this particular they vary much, as it depends on their having had more or leſs time to propagate; I have taken out of one liver, 870 in number, beſides many fragments, and excluſive of thoſe which were cut in pieces or deſtroyed in opening the liver. And in another liver I have ſeen but ten or twelve.

They are found in many different kinds of beaſts. I have been

informed by Hunters, that they have found them in Stags, wild Boars, and other kinds of game, both great and ſmall. I myſelf have ſeen them frequently in Calves, and once in a young Bullock. Sheep are infeſted by them even from the womb of the parent, and Lambs of a year old and upwards, as well as aged Sheep.

As to the production and propagation of theſe animalcules, I conſider as idle tales, what ſome writers aſſert, of their being generated by putrefaction or decayed ſubſtances, immoderate wet or heats, and other equally ſenſeleſs imaginations; and I lay it down as a certain truth, that theſe, as well as all other ſmall living creatures, are produced from their like, by the means of eggs, ſeed, or ſpawn, according to the nature implanted in them at their firſt creation. And it ſeems to me moſt probable, that theſe animals, with their eggs, find their way into the bodies of Sheep, (and which we may ſuppoſe to be the caſe alſo with other inſects and their eggs,) in the following manner; namely, that in wet ſummers and autumns theſe animalcules, which are originally bred on the ſurface of the earth, may, with the water in which they live, be ſwallowed by the Sheep; and I have been confirmed in this opinion by converſing with Countrymen, Huntſmen, and Butchers, on the ſubject. But I am not of the opinion that after being ſwallowed, they do themſelves force their way out of the ſtomach and bowels into the gall-bladder; I rather conclude, from reaſon and my own experience,* that their ſpawn or eggs may, with the oily part of the chyle in the infected beaſt

* It muſt ſeem ſtrange to us that a creature, originally bred in the water, ſhould find a proper receptacle for its life and growth in the warm bowels of an animal; and yet we daily ſee leeches, which are alſo bred in the water, and perfectly cold themſelves, ſuck the warm blood of the human ſpecies with an avidity ſcarcely to be paralleled. But, as Mr. Leeuwenhoek, in one part of his works obſerves, we may wonder at theſe operations of Nature, but admiration, and nothing more, will be the reſult of our cogitations.

be carried into the veſſels of the gall bladder, and there fix themſelves; foraſmuch as theſe veſſels are lined with a ſlimy and tenacious ſubſtance, and alſo becauſe the gall is not like the blood, in continual circulation, but is retained in its veſſels, or emitted, as the calls of the animal œconomy require. Again, they are found ſwarming in the liver, where they produce tumours and calloſities, and cauſe the colour of it to change. And it ſeems to me not at all ſurprizing that theſe animalcules ſhould live and be nouriſhed in the juices of the gall, for every living creature has a ſituation and ſpecies of food peculiar to itſelf. Sea-fiſh die in freſh, and river-fiſh in ſalt water. A worm cannot live in the air, and a fowl expires in the earth. What wonder is it then that the creature of which we are treating, when introduced into the body of another animal, ſhould find its peculiar place of life, growth, and increaſe, in the veſſels of the gall, and in the gall itſelf?

In the laſt place, like as we experience, that many living creatures are found in the human body, producing diſeaſe, pain, and death itſelf; ſo it is my opinion, that the animalcules of which I have been treating, and which are ſometimes found together by thouſands, may produce the following miſchievous conſequences:

Firſt, the extraordinary diſtenſion of the parts where they harbour, as well by the growth and increaſe of their own bodies, as by the multiplication of their ſpecies or brood.

Secondly, by their biting or gnawing the parts they infeſt, ſo as at length to break or deſtroy their texture; and thus wholly, or in part, render them incapable of performing their functions.

Thirdly, by forcing their bodies into the ſmall tubes, and veſſels, whereby the delicate frame of thoſe tender parts is torn aſunder.

Fourthly, by obſtructing the paſſages in the veſſels, whereby the circulation of the juices is prevented, and an inflammation enſues.

Fifthly, by devouring and conſuming the nutritive juices, whereby

the adjacent parts are deprived of their ſupport and nouriſhment.

Sixthly, by clogging the veſſels with their excrements, their eggs or ſpawn, and the bodies of ſuch of the animalcules themſelves as die, whereby the motion of thoſe parts being impeded, the moſt fatal conſequences follow.

There are many other ways in which theſe creatures may prove noxious to animals, but thoſe which I have here enumerated may be ſufficient to give an idea of the reſt.

He, then, who can find out and practiſe a method whereby, without injury to the parts of the body where theſe vermin harbour, can prevent their gnawing the parts, their creeping about in the inteſtines, and, what is worſe, their dying there; or rather, can diſcover how to expel them, while alive, out of the body, will in this reſpect bid fair to effect a cure. It is laid down as a truth, that a diſtemperature of the blood and juices, whether proceeding from an ill conſtitution thereof, or from an interruption in the circulation, can cauſe many diſeaſes and their ill conſequences: but muſt it therefore be deemed unreaſonable to attempt proving, that animalcules being found in the juices, or even in the more ſolid parts of the body, may alſo produce diſeaſes? The firſt of theſe points is mere matter of theory or argument; of the ſecond, more certain proofs can be brought; conſequently, it ſeems more rational, that thoſe perſons, who altogether rely upon their experience, ſhould, in their enquiries, diligently inveſtigate the reaſons on which they found their opinions.

I forbear to ſay any more on this ſubject, foraſmuch as what I have written is only for the improvement of medical knowledge, and as an incentive to the laborious enquirers after new diſcoveries in ſcience, the field of which, is indeed indefinite.

ADDITION, BY THE TRANSLATOR.

IT is proper to inform the Reader, that the preceding Eſſay has not Mr. Leeuwenhoek for its author, but is taken from a letter written to him on the ſubject by G. Bidloo, a profeſſional gentleman at Leyden, under date of the 21ſt March 1698, and publiſhed in the Dutch Edition of Mr. Leeuwenhoek's Works, though it does not appear in the Latin Verſion; but, as the ſubject is intereſting, and probably this Eſſay has not before appeared in any other than the Dutch language, the Tranſlator thought that it might be acceptable to the Engliſh Reader.

Since the peruſal of this Eſſay, the Tranſlator has had opportunities of converſing with ſeveral judicious Gentlemen, who are converſant in the grazing of Sheep, from whom he has collected the following particulars:

That in very wet ſeaſons, particularly towards the latter end of the year, a ſpecies of graſs ſprings up in the low and wet lands, by feeding on which, the Sheep are ſuppoſed to contract the diſtemper called the Rot. That, if the rains do not abound, until after the winter froſt has been experienced, the Sheep are not then obnoxious to this diſeaſe, but otherwiſe, if a wet ſeaſon precedes the froſt; and laſtly, that Sheep infected with this diſeaſe, do, for a time, appear fat and healthy, but, when the diſorder gets to a height, they fall away rapidly.

Theſe particulars ſeem to prove, that the diſeaſe called the Rot in Sheep, does in fact proceed from the animal deſcribed in the preceding Eſſay, which, being bred in the water, and adhering, with its eggs, to the graſs growing in watery places, is ſwallowed by the Sheep. And, it is probable that when the froſt precedes a wet ſeaſon, the animalcules and their eggs are killed by the froſt, and conſequently the Sheep eſcape: we may alſo conclude, that while this noxious animalcule is in an infant ſtate in the bowels of the Sheep,

it may not be particularly injurious, but when it arrives at a ſize to prey upon the liver, firſt, a ſickneſs, and waſting in the animal, and afterwards, death muſt enſue; and the Tranſlator has been informed by a gentleman's Gamekeeper, that he has frequently found Hares, dead of this diſeaſe, and that upon opening them, hundreds of the animalcules were found in their livers.

Theſe particulars the Tranſlator thought proper to notice, leaving it to thoſe who are qualified, to exerciſe their medical ſkill in the diſcovery of a remedy for this fatal diſtemper.

The animalcule before deſcribed is called in ſome parts of England a Fluke, in others a Loop, but moſt generally a Flounder, probably from the reſemblance it bears to the fiſh of that name.

* *The Author's opinion and reaſoning reſpecting the formation of that ſpecies of fuel which is called Peat†, and alſo with regard to the trees dug out of thoſe places where Peat is found: from whence he takes occaſion to propoſe and diſcuſs a queſtion, whether the Sea may not, in proceſs of time, become more elevated in reſpect of the Land.*

I HAVE heard many perſons deliver their ſentiments, reſpecting the manner in which that ſubſtance called Peat was produced in this country of Holland. The general opinion is, that the place where this Peat is found was, in former ages, nothing but a wood, and that the falling leaves and ſmaller branches or twigs of the trees, collecting together on the earth, did in proceſs of time, produce this ſubſtance, which is by us called Veen. It is alſo believed, that thoſe trees, numbers of which are found among the Peat, formerly grew in the ſame place, and were all blown down by ſome violent tempeſt of wind

* In this Eſſay, the Author departs from his uſual method of inveſtigating the works of Nature by the microſcope, and proceeds upon theory. It will be ſeen, however, that he does, in one inſtance, draw a very ſtrong argument in ſupport of his hypotheſis, from microſcopical examination.

† The words Peat, and Turf, are ſometimes uſed promiſcuouſly, though their true meaning is very different. Turf, properly ſo called, as denoting an article of fuel, is compoſed of the thick roots of graſs, pared off the ſurface of the earth on commons, and dried in the ſun. The bark of oak, after it has been uſed by the tanners, made up into ſquare pieces or cakes, and dried, is ſold in London for firing, under the name of Turf. But Peat, of which the author here treats, is found under the ſurface of the earth, ſometimes to a conſiderable depth.

from the North-Weſt, and that for this reaſon, the roots of all the trees ſo dug up at this day do point towards the North-Weſt.

Theſe opinions I have often controverted: for how can it be imagined, that ſo great a quantity of Peat could be produced from trees ſtanding together in a wood; inaſmuch as Peat is in ſome places found collected to the thickneſs of ten or twelve feet, and ſometimes more? Neither can it be conceived, how thoſe large oak trees, which are now found, lying in the midſt of the Peat, could ever have grown to their full ſize in ſuch a ſoil, for, a common ſtorm of wind would have been ſufficient to blow them down.

Again, it is well known, that thoſe trees which are found at a conſiderable depth in the Peat never have on them the ſmall branches on the ſtem, nor any ſmall ramifications on the roots, and all thoſe ſmall light branches of alders and willows which are found in Peat, are not (as far as I have ever known) firm or ſolid in their kinds, but very much decayed, the ſame as if they had been for ſeveral years expoſed to the air, or had died and withered on the trees, or were almoſt rotten. Theſe decayed portions of wood cannot, as I conceive, have grown in the places where they are now found, but muſt have been carried thither by ſome flood, or ſtream of water, and that they either floated on the water, or had lain expoſed to the air for ſeveral years, and therefore may properly be denominated decayed wood; and I remember, that on handling ſome pieces of willow about the thickneſs of a finger, which I myſelf ſaw dug up, I found them as ſoft and flexible as a withered carrot.

Now, if thoſe oak trees, which are found at a great depth in the Peat, had originally grown in the ſame place, ſuch trees would certainly be found with the ſmall branches on their ſtems and roots, if not in the whole, at leaſt in part, and thoſe not decayed, for in the very ſame places there have been found in the Peat, hazle-nuts, with their ſhells entire.

We know that theſe trees lye eight or ten feet below the ſurface of the Peat, which ſurface is, in ſome places, four feet lower than the ſea at low water; how, then, can it be conceived that thoſe trees could have grown in ſuch low lands, unleſs we ſuppoſe that the level of the ſea was at that time full twenty feet lower than it is at preſent?

To this may be added, what I have myſelf been an eye-witneſs to, that a violent ſtorm from the North-Weſt has ſo agitated that river which we call Hollands Diep, or Haring Vliet, as to tear up from the bottom large portions of a ſubſtance ſimilar to our Peat, but ſo light, as to be carried by the waves againſt the banks, and there left, ſometimes in pieces larger than a cart-load, which ſubſtance I was told the poorer ſort of people carried away for fuel. Now, it is impoſſible that this Peat-like ſubſtance raiſed from the bottom of the Haring Vliet, and which, like Peat, is compoſed of leaves, ſmall fibres of the roots of trees, and other vegetable ſubſtances (and who knows how deep the bed thereof may be?) could ever have grown in that place.

I once ſaw Peat taken up from the depth of ten feet, in a watery place, where it had never before been dug. I examined the texture of it, and found it in part to conſiſt of an herb called heath, which herb does not grow in our Peat-lands. And I have alſo ſeen Peat dug up at a conſiderable depth under the ſands, not in regular ſtrata or beds, but in broken interrupted patches, and ſometimes in a large body collected. This Peat I examined, and found that it conſiſted of leaves of trees, the roots of graſs, the ſtalks of leaves, and very ſmall pieces of wood; in ſhort, there is no vegetable ſubſtance that grows wild of itſelf, but what, upon an accurate inveſtigation, will be found among Peat.

Some years ago, being on a journey at a ſmall diſtance on this ſide of Haerlem, I ſaw in a meadow by the road ſide, a labourer digging in the earth in a cavity as deep as an ordinary man's height; and, being curious to know what he was taking up, I alighted from my carriage, and found that it was Peat which was laid by in pieces to dry for firing.

In the place where this man was digging, the Peat lay only in ſmall parcels, or collected portions, and near the ſame ſpot there was not any token or appearance of Peat. I was at the ſame time ſurprized, to ſee lying on the ſand among the Peat, a certain ſubſtance of a fine blue colour, and I was told, that, near the place, it had been found in a larger quantity, and enough of it collected to fill a ſmall caſk, which had been carried away and ſold.

At another time, in paſſing through the town of Helvoetſluys, I obſerved before the houſes of ſeveral poor people, parcels of Peat piled up to dry, and I was told that it was good fuel, but produced a diſagreeable ſmell, and that it had been dug out in enlarging the dock for ſhips; and on breaking ſome of this Peat in pieces, I perceived in it ſome ſmall ſhining particles, which induced me to carry home a ſmall quantity of it, that I might examine it by the microſcope.

I was informed, that this Peat was dug in a place where there had formerly been a dyke, or bank againſt the ſea, and that the peat did not lye in a regular bed, but only in three places, and that under it was the kind of ſand we call klapzand, all which, upon examination, I found to be as related. Hereupon I concluded, that this ſand, called klapzand, had in former times been the ſea-ſhore, and that the Peat had by floods been brought to the three places where it was now found, and afterwards covered with ſand from the ſea, or that waſhed down the river.

On my return home, I examined this Peat by the microſcope, and found, that the before mentioned ſhining particles were the ſeeds of ſome plant, which, if they had been larger, might have been taken for beans, but theſe were ſcarcely the fifteenth part of an inch in diameter. Other ſhining particles I alſo obſerved in this Peat, which, upon a more accurate examination, I found to be pieces of the ſkins of thoſe flying inſects which are produced by tranſmutation from maggots or caterpillars, who hide themſelves in the earth; and, among others, I ſaw ſome pieces of an inſect of the beetle kind, which, as it frequently

creeps into the earth, has its wings covered with a kind of ſhell or caſe for their defence, in like manner as we obſerve in thoſe inſects which are called by children cockchafers and ladybirds.

I alſo diſcovered divers pieces of the bodies of various ſmall animals, in which I could diſtinguiſh thoſe little cavities or ſpots which are obſerved on inſects, particularly on the caſes covering the wings; alſo on ſome of theſe fragments I ſaw very minute hairs, ſuch as the bodies of inſects are generally covered with, likewiſe ſome fragments of wings with hairs on them. I found alſo a kind of ſting of ſome inſect, and at the extremity of it an aperture, ſuch as is ſeen in the ſting of a ſcorpion; in a word, I found an incredible number of particles or broken fragments of inſects of various kinds and ſizes, conſidering the ſmall quantity of Peat in which they were contained, ſo that it may fairly be concluded, that all thoſe inſects had been promiſcuouſly collected together when the earth on which they lay had firſt been waſhed away.

In the ſame portion of Peat were various particles, appearing to the naked eye like the ſtalks of graſs or plants, and ſuch I found them by the microſcope to be, and by it I plainly perceived the tubes or veſſels of which they were compoſed. I alſo diſcovered ſome few particles, which ſeemed to be the huſks of ſeeds, and others which I imagined were the rinds or bark of twigs.

All theſe particles, of the many different kinds I have enumerated, were contained within the compaſs of a portion of Peat not exceeding a cubic inch in ſize.

From theſe obſervations it appears, how incorruptible are ſome ſubſtances, when buried deep under ſand and water, when the ſame ſubſtances being expoſed to the air, and in frequent agitation, are ſo divided and broken that they eſcape our ſight, and then we ſay they periſh; and who knows whether this Peat-like ſubſtance might not have lain for ſome thouſand years under the ſand and ſea water before the place became firm land?

It is well known, that not only in Holland, Guelderland, and Utrecht, but alſo on all the ſea-coaſt, as far as Holſtein, much Peat is found; and if it be true, as is generally believed, that not only England and Scotland were formerly united to Ireland, but that the Orcades, Shetland, and Faro, and the other ſmall iſlands near them, were formerly united (which iſlands being rocks, or rocky on their ſhores, are able to reſiſt the force of the ſea), and that in theſe iſlands this Peat-like ſubſtance is alſo found, we can without much difficulty ſolve the queſtion, if we ſuppoſe that theſe larger and ſmaller iſlands, by violent ſtorms and high tides of the ocean, may have been ſeparated from each other, and that the earth or ſoil which was then carried away, was covered with various trees, graſs, and herbs; all theſe ſubſtances floating on the ſea, might, by the tides and North-Weſt winds, be driven to the places where they now lie; and the trees which we find lying with their roots pointing to the North-Weſt, muſt of neceſſity be depoſited in that poſition: for, as the roots of trees are heavier than the upper parts of the ſtem, thoſe roots muſt ſink deepeſt in the water, and, being dragged along the bottom of the ſea, the ſtems would be driven foremoſt, and cauſe the trees, when waſhed on the land, to lye with their roots towards the North-Weſt. The heavier ſubſtances, as ſand and clay, which had conſtituted the ſoil ſo carried away by the ſea, would, by their weight, ſink to the bottom, and, taking the ſame courſe with the Peat, would be thrown upon it, and produce a ſandy ſhore, as we now perceive it.

It is further to be conſidered, that our rivers, the Rhine and the Maes, do every year bring down with them great quantities of ſoil, and particularly in the ſpring time, becauſe at that ſeaſon, by the ſun and rains, the ſnow is melted on the tops of the high mountains, and, running over the lands, waſhes away with it great quantities of ſand, clay, and earth, and theſe, by reaſon of the ſwift current of thoſe waters, find no reſt until the rivers, becoming wider at their mouths,

and meeting alſo the flood from the ſea, their current is diminiſhed, and the ſand ſubſiding, produces ſhallows. In theſe ſhallows, the clay and earthy ſubſtances alſo ſettle, becauſe in thoſe places the waters have little motion, in proportion to what they have higher up the rivers, and, by this means it is well known that there is a continual increaſe of dry land in ſome parts of our ſhores.

If we obſerve attentively our ſea-coaſts, we ſhall in ſome places, even thoſe which the ſea daily breaks againſt and waſhes over, obſerve large pieces of black earthy matter, very compact and cloſely cohering, and which lye partly covered with ſand, and partly overflowed every tide. Theſe portions of earthy matter ſo depoſited, produce a ſtrong argument, to convince us that our ſhores thus waſhed up by the ſea, were not merely formed by ſmall quantities of ſoil gradually depoſited, but by large portions or fragments of land. And, who knows how long ſuch fragments of land might, by reaſon of their gravity, lye at the bottom of the ſea before they were thrown upon the ſhore, which, in all probability, could not be effected otherwiſe than by violent ſtorms, and that, many years after the ſhoaly or ſandy bottom was firſt formed.

The magiſtrates of Leyden had it lately in contemplation, if it could have been done, to make a channel, outlet, or opening for water, into the ſea at Catwick, in the place where the Rhine formerly diſembogued itſelf; but they found the undertaking to be impracticable, by reaſon that the level of the ſea was too high at that ſpot. This, at firſt, appeared ſtrange to me, as I could not conceive how the ſea could obtain a greater altitude than in former ages, ſeeing there is not a greater portion of waters on our terraqueous globe, than at its firſt formation. But the difficulty ceaſed in my mind, when I conſidered, what quantities of fine ſand and ſlime, or clay, are continually carried down our rivers, inſomuch as to make firm land, where formerly it was deep water; and further, what large rivers there are in other parts of the world, all which carry great

quantities of ſuch ſand and ſlime into the ſea; whereby, at the mouths of thoſe rivers many levels of marſh land are produced, while on the other hand, moſt countries far diſtant from the ſea are mountainous.

If we then conclude, that, by all theſe rivers, a great quantity of ſand and earth, and whatever is heavier than the water, is depoſited in the ſea, it neceſſarily follows, that the ſea muſt from time to time be more elevated. Again, by earthquakes, large portions or tracts of land are buried in the ſea, leaving nothing but lakes in their place; and we have inſtances of a volcano or burning mountain caſting ſo many rocks and ſtones into the ſea, as to raiſe iſlands where before it had been deep water.

In the year 1692, by an earthquake in the iſland of Jamaica, a large ſpace of land was ſwallowed up, and converted into a lake; and, at the diſtance of thirty miles from the ſea, two hills, by the ſide of a river were thrown down, cauſing the river to take another courſe; from which new channel, a great quantity of earth muſt have been carried into the ſea: and although the coaſt of Norway, and that of Ireland, Scotland, and part of England, are rocky cliffs, yet their rivers muſt continually carry much ſolid or heavy matter with their waters, and, the beating of the waves againſt the cliffs, will carry theſe kinds of ſubſtances into the bottom of the ſea, and ſo elevate its ſurface.

To ſome perſons this aſſertion may ſeem ſtrange, as judging that the great extent of the ſea bears no proportion to the ſmall quantity of earth which the rivers waſh into it; and that therefore, the ſea cannot be ſo much elevated, as to make any perceptible difference in ſeveral hundred years.

In order to ſet this matter in a true point of view, I have made a queſtion with myſelf: Suppoſing the mountain called the Peak of Teneriffe, to be ſunk in the ſea, what elevation would it produce in

the general ſurface of the water? Now, (conſidering the whole of this globe to be one third part land, and two thirds water) I compute that the whole ſurface of the waters would be thereby raiſed between one fourth and one third of an inch. And, ſuppoſing all the rivers in the world, which are very numerous, (for according to our maps Spain and Portugal only, contain one hundred) do yearly carry with their waters into the ſea ſo much earth as is equal in ſize to one half of the Peak of Teneriffe, the ſea would, in the ſpace of one hundred years be elevated nearly two feet.

This being ſo, it is not to be wondered, that we find our flood tides, in ſtrong winds from the North-Weſt, to riſe higher than they were known to do in former times, and that the Rhine, which heretofore fell into the ſea at Catwick, cannot now have any outlet that way; and laſtly, that on the ſame account, we are obliged to raiſe our dykes higher than formerly. Indeed, we may conclude, that if in a courſe of many years, there ſhould not be more ſpace given to the waters of the ocean, by earthquakes or ſubterraneous fires, producing cavities in the deep, the low lands near the ſea will at length be overflowed.

As to the quantity of land excavated in digging Peat, which ſome may imagine affords room to the waters, the ſpace of earth or ſoil ſo taken away, does not, in my judgment, amount to a thouſandth part of the ſand and clay which is brought down the rivers, and beſides, the places ſo excavated are, for the moſt part, afterwards drained.

On the effects of Acids in the Stomach, and the uſe of Fiſh Diet, with a particular deſcription and examination of the liquor or ſubſtance named Runnet, which is uſed in the making of Cheeſe.

IT is the opinion of many medical perſons, that various diſorders in the human frame are cauſed by acid in the ſtomach, which coagulates the juices; and ſome condemn the uſe of acids, and alſo of fiſh, as articles of food. But to theſe opinions I cannot ſubſcribe, for, at a town in my neighbourhood, where the people get their living by fiſhing, and principally feed on fiſh, eſpecially when they are on the ſea, the men are very robuſt and healthy, even to a great age; and, with reſpect to myſelf, I have experienced, that, when my habit of body has been indiſpoſed, I have been greatly refreſhed by eating fiſh, with ſauce compoſed of a mixture of butter and vinegar, and I never found acid ſauces diſagree with me. It is alſo my opinion, that a fiſh diet is more wholeſome than fleſh, particularly to thoſe perſons who do not uſe much exerciſe, becauſe fiſh is more eaſily comminuted and digeſted in the ſtomach and bowels than fleſh; and, as fleſh affords a more nutritious ſubſtance, ſuch ſuperabundant nutriment is, in my opinion the ſource of many diſeaſes. And, I think it may be made appear, that the coagulation or curdling of food in the ſtomach, when cauſed by acid, is not prejudicial, but rather conducive to health.

In the markets which are held weekly in our town, it is uſual to expoſe to ſale, that part of the inteſtines of calves which is called

the Maw; this is falted, and kept in caſks, and, with the pickle in which it is preſerved, goes by the name of Runnet. It is purchaſed by farmers, and when poured on milk* curdles it, of which curd, cheeſe is made. Some of this pickle I purchaſed, in order to examine it more accurately, but was obſtructed in my enquiry, by the numbers of ſaline particles in it.

I therefore purpoſed to procure from a butcher, ſome of the liquor when newly taken out of the maw, as ſoon as the animal was killed; and I was informed, that if a calf had ſwallowed any milk a few hours before it was killed, there would be found in its maw a quantity of coagulated or curdled milk, which it was cuſtomary for the butchers to take out and preſerve with ſalt in a jar, (ſome of which curd was ſhewn to me), in order to ſell the ſame to the farmers, who found by experience that a ſmall portion of this curdled milk, was of more ſtrength or virtue for their purpoſe, than the liquor in which the maw was pickled.

I then went to another butcher's, where I ſaw the maw of a calf, wherein, although the animal had not ſucked for the ſpace of twenty four hours before it was killed, I perceived ſome portions of curdled milk, larger than a walnut; theſe I cauſed to be waſhed in clean water, and carried them home with me, and I was much ſurprized to find them as hard to the touch as new made cheeſe.

This curdled milk I put into a glaſs, and poured on it rain water, ſo as to cover it about an inch, and then broke the curd into ſmaller pieces, in order that the ſaline particles, if any there were in it, might be diſſolved by the water; and, after it had ſtood thus for ſome hours, I ſtrained the water through a filtering paper, into a new and perfectly clean glaſs.

* Rinnen in German, and *ronnen* or *runnen* in Dutch, mean to curdle; this gives us the true derivation of the word Runnet.

Some of this filtered water I poured on a portion of wine, in order to ſee whether it would have any effect on the ſaline particles which are in wine, but, after it had ſtood ſeveral hours, I could not perceive any alteration; I therefore determined to try the experiment with vinegar. And, as the vinegar which is commonly ſold, is for the moſt part adulterated, I took white wine vinegar, which I had kept with marygold-leaves in it for five and twenty years, and was uncommonly ſtrong, and mixed with it a ſmall quantity of the before mentioned liquor, but I ſaw no other ſaline particles in it than thoſe which are found in vinegar. I obſerved, indeed, ſeveral globules of oil, which in all probability proceeded from the marygold flowers.

But, when I took a ſmall quantity of new milk, and mixed with it a very little of the before mentioned water, on bringing it before my eye as ſoon as I poſſibly could, I ſaw moſt of thoſe round particles which cauſe its white colour, curdled together, and an inconceivable number of ſmaller particles, ſwimming among the curdled ones, from whence I concluded, that theſe ſmaller particles were of a different nature from the coagulated ones; I alſo ſaw in the fluid or whey various pellucid globules of different ſizes, the ſmalleſt of which were no larger than globules of blood, and the largeſt of theſe pellucid globules were twenty-five times that ſize; all theſe I concluded to be thoſe particles in the milk, of which butter is compoſed.

From theſe obſervations it appears, that this liquor called Runnet, which coagulates or curdles milk, does not take any effect on wine or vinegar, neither of which are adapted to the food of calves.

I was informed by the butcher, that the ſame curdling of milk, took place in the ſtomachs of ſucking lambs; and moreover, that if lambs were taken from their dams and fattened with cow's milk, it would be curdled in larger quantities, by reaſon, (as he judiciouſly added) that ewes milk has more particles of fat in it than that of cows.

After this, I mixed new milk with a large quantity of Runnet, to ſee whether thoſe ſmaller particles which I have before mentioned to have ſeen ſwimming in the whey, would thereby be coagulated, but they ſtill continued to preſerve their figure.

Upon examining the before-mentioned filtered liquor by the microſcope, I ſaw in it an inconceivable number of uncommonly minute particles, to which, by reaſon of their exceeding ſmallneſs, I could not give any other name than that of globules.

Whether the globules or ſalts in the Runnet, have ſuch an effect on rain water, as to cauſe any of its particles to coagulate, ſo as to become viſible by the microſcope, I have not yet been able to diſcover.

I ſeveral times tried the experiment of pricking my finger with a needle, and, immediately mixed ſome of this liquor with the blood, to ſee whether any of its particles would thereby be coagulated: on viewing the ſame through the microſcope, it exhibited a curious and pleaſant ſpectacle of vaſt numbers of the globules of blood, rolling one over another, but they were ſo far from being coagulated by the mixture, that they ſeemed more fluid than before.

After this mixture had ſtood about the ſpace of half a minute, I perceived in it many ſmall pellucid particles, which by degrees grew larger, but yet were ſo minute, and ſo much covered by the circumjacent particles, that I could not clearly diſcover their figure; but, to the beſt of my judgment, they were irregular ſaline particles, appearing all of different ſhapes, and adhering together, in like manner as we obſerve in ſugar-candy. Now, whether this appearance was compoſed of ſalts in the blood, or ſalts in the milk, or both, I am not able to diſcover.

I ſeveral times applied a drop of the before-mentioned filtered liquor to my tongue, and I judged it to have more of a bitter than an acid taſte; whereupon I conſidered, whether its property to curdle milk, might not be derived from the gall.

I therefore went to a butcher's, to ſee whether the gall was not emptied into the maw, but I found that the gall bladder did not diſcharge its contents into the maw, but farther down, where the bowel grows narrower; this gall bladder I cauſed to be cut off ſo as to leave the veſſel through which the gall paſſes, joined to the bowel, and having bound both ends of theſe with a thread, I inflated the gall-veſſel with wind, but I found the parts to be ſo contrived that not the leaſt portion of water, or even of air, could paſs out of it into the maw.

When ſome of this Runnet had ſtood with a little water on it in a glaſs, for the ſpace of two days, it acquired as acrid a ſmell, as we perceive in ſour curdled milk.

I at one time, received from a butcher, the gall bladder of a calf, which was entirely void of gall, whence I ſuppoſed that its contents had been ſpilled by accident, but I afterwards underſtood that no gall had been in it, and that the like appearance was often obſerved.

But, what ſhall we ſay, when we ſee in how high eſtimation tobacco is held, and acids altogether condemned; as if all our bodies were exactly of the ſame diſpoſition or conſtitution.

For my part, I have for many years been uſed to ſmoke tobacco for the cure of the tooth-ach, but I have often found that before I ſmoked half a pipe, I was ſo ſick, as to be obliged to lie down near the fire, and ſo much diſordered, that I could not even endure to be ſpoken to; whereas, on the contrary, every kind of acid, whether uſed in food, or taken by itſelf, agrees perfectly well with me. In ſhort, we can much better judge for ourſelves as to what agrees or diſagrees with our conſtitutions, than pretend to adviſe other people what is good diet, or the contrary.

With regard to the curdled milk, which I have mentioned to be taken out of the calf in hard pieces, it ſeems to me probable, that the milk at firſt was but lightly curdled, and that the frequent contrac-

tions of the bowel where it lay, which in the courſe of nature are performed many times in a minute, were the cauſe of its being found in that ſtate.

Seeing now, how powerfully coagulation is performed in animals, we may conclude, that ſomething of the ſame kind muſt take place with the food in our own ſtomachs, in order to render the ſame nutritive to us. And who can tell, how far ſuch coagulation may take place, not only with milk, but alſo with wine, vinegar, ſalt, and other parts of our food? This, however, is certain, that if a ſucking child caſts up the milk, on account of having ſwallowed more than its ſtomach can contain, ſuch milk, though juſt before taken from the breaſt, is in a curdled ſtate; conſequently we muſt conclude, that coagulation in our ſtomachs is a neceſſary part of the animal œconomy.

If milk in the ſtomachs of ſmall animals was not curdled, it would in a few hours paſs through their inteſtines, and afford but little nouriſhment to their bodies. And, in this opinion I have been confirmed by the experience of the butchers, from whom I find, that when the excrements of calves or ſucking lambs are thin and fluid, they thrive but little, and, that at thoſe times, no curdled milk is found in their ſtomachs.

I am aware, that theſe my obſervations, may diſpleaſe ſome perſons, as thinking that herein I am going out of my province; but, thoſe conſiderations weigh little with me, foraſmuch as every judicious perſon knows, that Phyſicians themſelves, in many things proceed merely by gueſs, and therefore, I aſſume to myſelf the liberty of offering my conjectures on this ſubject.

ADDITION BY THE TRANSLATOR.

Almoſt all the arts, which contribute to the ſupport or comfort of human life, have been the reſult of long and repeated experience. I will inſtance in the two moſt neceſſary articles of food, which are bread and beer, reſpecting which, a celebrated writer of the laſt age thus expreſſes himſelf:—"The arts of "brewing and making bread have, by ſlow degrees been brought to the per- "fection they now are in, but, to have invented them at once, and, * *à priori*, "would have required more knowledge and deeper inſight into the nature of "fermentation, than the greateſt Philoſopher has hitherto been endowed with; "yet the fruits of both, are now enjoyed by the meaneſt of our ſpecies."

Cheeſe, however, another principal article of food, at leaſt among the poor, was moſt probably brought into uſe, *à priori*, by adverting to the change made in milk, from a fluid to a ſolid, in the ſtomach of the calf, and by imitating nature in the manner deſcribed in the preceding Eſſay. To preſerve the concreted or hardened ſubſtance, in a wholeſome ſtate, for a length of time, human invention added ſalt, and, by theſe two eaſy operations, is produced that, which is now a luxury to the rich, and a ſupport to the poor.

How the change in milk, by the mixture of Runnet, is produced, Mr. Leeuwenhoek's induſtry, we ſee, has not been able to diſcover; we can only therefore admire the manner in which nature operates, to produce this effect. For, there is no other known ſubſtance that ſo effectually curdles milk, and, though the taſte of Runnet is of itſelf very nauſeous, yet none of this diſagreeable taſte is imparted to the curd; on the contrary, that which is called cream cheeſe, or new cheeſe, being merely the curd, without any mixture of ſalt, is of a ſweet and delicious taſte, and is produced as a dainty at our tables.

* The expreſſion, *à priori*, means, in logic, or in practice, to argue or to act upon known and eſtabliſhed principles, from whence a certain concluſion or effect enſues; *à poſteriori* means, where, arguing from the effect, we trace it backwards to its cauſe.

Of the Snail or Inſect found on the Vine, alſo on the nature of Sage, and whence its virtue proceeds; with ſome obſervations on the manner in which different animals emit their poiſon.

A Gentleman of ſome conſequence in this country, upon a certain time, put into my hands, a parcel of ſmall whitiſh eggs, together with ſome dry earth, in which they were found; and deſired that I would endeavour to diſcover what ſpecies of animal would be produced from them. The axis of theſe eggs was nearly equal to one fifteenth part of an inch.

One of theſe I diſſected, and found in it a thin fluid, mixed with round particles, or globules; the reſt of them I put into a glaſs, but their contents in a few days entirely evaporated, and the ſhells, which were very brittle and tender, upon the liquid they contained being exhauſted, became ſhrivelled, ſo that no living creature proceeded from them.

The following year, the ſame gentleman brought to me ſome more of thoſe kind of eggs, which I treated in the ſame manner as the former, but with no better ſucceſs.

In the month of July, in the third year, I received from the ſame perſon a larger parcel of thoſe eggs, which were mixed with about an handful of moiſt earth.

Seeing this, I began to conſider, that perhaps, the reaſon why the liquor being evaporated from the former eggs, had thereby prevented their producing any living creature, was, that in dry earth they be-

came barren, and that in their nature they required to be kept moiſt; conſequently, that if I treated them in the ſame manner as the former, I ſhould never obtain my wiſh to diſcover their ſpecies. I therefore put theſe, and the moiſt earth wherein they lay, into a glaſs tube, about ten inches long, and three quarters of an inch wide, one end of which I had cloſed together by heat, and the other I ſtopped with a cork, by which means whatever moiſture might evaporate from the earth, would be confined by the glaſs, and, there condenſing, the greater part of it would fall back on the earth, and keep it, and the eggs, always moiſt.

This tube I placed in my cloſet, ſo as to be continually in the way of my notice, and, after ſome days, I ſaw, to my great ſurprize, two ſmall * Snails, of that ſpecies which infeſt the branches of vines, (and which are called by us Wyngaart-ſlakken, Vine-ſnails or Vine-ſlugs) on the inſide of the tube, and which had crept out of the earth contained in it.

I then took out of the tube an egg, or rather what was now become a ſmall Snail, with part of the egg ſhell adhering to it, and put it into a ſmaller tube, in order to examine it by the microſcope more accurately; and thereupon I perceived in one of the horns a very rapid motion, performed in a veſſel, apparently an artery, and which I judged to be about one fourth part the ſize of an hair. This motion was not an uniform or continued one, but by fits, or pulſes, and, ſo quick, that I judged the juices in the veſſel were propelled forward, three times within the period of one pulſation in the human body; and I concluded, that this veſſel muſt certainly be an artery, and not far diſtant from the heart, becauſe the quick pulſations I have noted, could not, otherwiſe, have been ſo diſtinctly ſeen.

The next morning this ſmall Snail was dead; as I gueſſed, for want of food, for the others of the ſame ſize, which were in the larger

* Mr. Leeuwenhoek has not given a figure of this animal.

tube with the earth, continued alive; the next day more of the ſame kind of Snails came out of the eggs, and the third day many more.

I often contemplated one of theſe Snails, while adhering to the inſide of the glaſs tube, and, with great pleaſure, I ſaw through its ſhell (which was ſo pellucid as to tranſmit the light) a part of its body not larger than a grain of ſand, and of an oval ſhape, which alternately was contracted and extended, each alternate motion being performed in the ſame ſpace of time as is required to pronounce diſtinctly a word of four ſyllables. This little point or corpuſcle, I deemed to be the creature's lungs, and the reciprocating motion, that of reſpiration.

I have formerly often diſſected theſe kind of Snails found on Vines, chuſing for that purpoſe the largeſt I could find, in order, if poſſible, to diſcover the manner of their generation, and whether any young ones were to be found in them, but hitherto without any ſucceſs; and now, almoſt by accident, and with little trouble, I plainly perceived that theſe creatures were propagated by laying eggs.

It has frequently been matter of great wonder to me, to obſerve in the ſpring, young Snails of this ſpecies on the Vine branches, when I could not conceive, how they could have been bred and brought forth ſo early in the ſeaſon. But, ſince it now appears, that they are produced from eggs, the difficulty ceaſes, becauſe we can eaſily conceive how theſe animals may be hid in the earth all the winter in the egg, and break out from thence, as ſoon as the firſt warmth of the ſpring returns.

I have likewiſe often obſerved full grown Snails of this ſpecies, whoſe ſhells were covered with earth or clay, as if they had been newly dug out of the ground, and never could ſatisfy myſelf as to the cauſe; but this is alſo now accounted for, becauſe, as they muſt creep into the earth to depoſit their eggs, it is natural to ſuppoſe that ſome portions of earth or clay may be left ſticking to their ſhells or horns. And, if any perſon ſhould wonder how theſe creatures can

creep into the earth, I can ſatisfy him in that point, from my own experience; for I have frequently ſeen, after I had picked ſeveral of them off the tree, and not only thrown them on the ground, but preſſed them with violence into the earth, by ſtamping on them with my foot, yet, in a ſhort time, if their ſhells eſcaped unhurt, they would find their way out again.

In the month of Auguſt, I invited the friend I have mentioned, to my houſe, and acquainted him with the manner I had treated the eggs he had ſent me, and ſhewed him the Snails which they had produced, with which he was greatly pleaſed; and told me he had rather ſuppoſed, that the ſpecies of lizard commonly called Efts would have been the produce. The next day, he brought to me a very large Snail of this ſpecies, the ſurface of whoſe ſhell was covered with moiſt earth, juſt as if it had newly crept out of the ground; and he informed me, that, while he was bringing it, he perceived it lay an egg. Hereupon, I put this Snail into a glaſs tube, about ten inches long, and wide enough to give it full liberty of moving about; and within half an hour it laid ſeven eggs, which I perceived ſticking to the glaſs, and in two hours time as many more; but, when I next examined it, I found that in creeping about the glaſs it had broken them all, and in two days it died, as I ſuppoſe for want of food, without laying any more eggs.

The ſmall Snails, which, as I before mentioned, were produced from the eggs, did not live above two or three days, and I perceived that the ſhells from whence they had iſſued were very white, but the remainder of the eggs which had not produced any young ones, and were barren, were of a dark colour, and of a watery appearance.

It being now demonſtrated by the foregoing obſervations, that theſe Snails are produced from eggs, the old eſtabliſhed error muſt be abandoned, which thoſe adopt, who dream that theſe creatures are produced from corruption, or the decayed leaves of trees; and

thence conclude, that, if ſuch leaves are not taken out of gardens, theſe Snails will be bred from them. Whereas, we ought rather, on conſidering the matter, to ſay, that if the leaves which fall in autumn are left in gardens, the eggs depoſited by theſe Inſects in the ground, the ſurface of which is covered with ſuch leaves, will be the better defended from the winter's cold, and conſequently more of thoſe animals will be produced in the following ſummer.

A certain Author, of the name of Kircher, having publiſhed to the world, that he had, by his microſcope, diſcovered on the leaves of Sage ſomething like a ſpider's web, woven by ſome ſmall inſect, and having thereupon founded an aſſertion, that thoſe who ſhould eat of Sage leaves, without waſhing them, would be poiſoned, I was requeſted by ſome learned friends, to examine into the truth of this aſſertion.

I had many years before this time, frequently inſpected the leaves of Sage, and always found that they were, in many places, covered with ſmall globules, but I never perceived on them any animalcules, nor their eggs, even by the aſſiſtance of the microſcope.

Upon this occaſion, I procured ſome Sage, not only the green ſort, but that, which, becauſe its leaves are yellow at the edges, is called variegated Sage. This I examined by the microſcope, and perceived the leaves to be covered with many capillary or hairy parts, too ſmall to be diſcerned by the naked eye; and ſo cloſely ſet together, that there was not a place in the leaves, of the breadth of an hair without them, and, I cannot give them a better name, than capillaments, or ſmall hairs, becauſe, like the hairs of animals, they all terminate in a ſharp point. And I ſuppoſe, that Kircher had imagined theſe capillaments to be the webs of ſpiders.

At the extremities of many of theſe capillaments, I perceived certain globules, which, through the microſcope, appeared no larger

than grains of ſand ſeen by the naked eye; and theſe globules ſeemed to me to be filled with an oily ſubſtance. But I could not diſcern the leaſt trace of any living animalcules on the ſurface of the leaves, and I am certain, that, had there been any ſuch, though an hundred millions of degrees leſs than a grain of ſand, they would have been viſible by my microſcope.

This oil, wherein the virtue of Sage conſiſts, is produced on every leaf of it in ſuch abundance, as no one would believe, but from experience; inſomuch that one can ſcarcely touch a leaf of Sage, but an incredible quantity of oily particles will adhere to the fingers.

My admiration was greatly excited, by obſerving that the greater number of the capillaments I have mentioned, were formed with three joints, and ſome, which ſtood on the veſſels of the leaves, with four. Theſe joints I do not remember to have ſeen in the capillaments on any other leaf, but whether that is to be attributed to my want of attention, I do not know.

When Sage is dried, its leaves exhibit a whitiſh colour, and that is cauſed by theſe capillaments, which, lying thick one on another, do, by their tranſparency, produce that whiteneſs.

This ſame Kircher, in his writings, gives it as his opinion, that Sage, and alſo Fennel, are very wholeſome herbs, but, that in them is produced a maggot, which, being inadvertently eaten, will cauſe grievous ſymptoms, and even death itſelf; and he moreover pretends to have found by experience, that there is no plant which does not breed ſome maggot or moth; but ſurely, if he had been provided with a good microſcope, and had underſtood how to uſe it in the diſſection and examination of minute animals, he never could have broached ſuch abſurdities.

For my part, it is my fixed and ſettled opinion, that no leaf, no tree, nor any root, ever did, or ever can, produce or breed any animal endued with life and motion. But, a ſmall animal may lay its eggs, or

depoſit its young, on the leaf or fruit of a tree, which young one, when depoſited, or when hatched from the egg, may make its way into the leaf or fruit, and there find nouriſhment to promote its growth.

It is an eſtabliſhed axiom among Philoſophers, that, nothing can come of nothing; how then can a being or ſubſtance void of motion, produce a creature endued with motion and life? And this is certain, that, whenever we diſſect or examine ſmall animals, the wonderful fabrick of their bodies, both externally and internally, ſtrikes us with aſtoniſhment.

As to the opinion, that venomous animals do ſhed their poiſon on fruits or leaves, I do not ſee that this can be ſaid of the Scorpion, nor that poiſonous ſerpent called the Rattle Snake, neither of the Spider, nor the Indian Millepeda, becauſe, as far as I can underſtand, they have not power to hurt, by ſpitting or voiding their poiſon on any object, becauſe they cannot caſt it to any diſtance, but they do miſchief, by injecting it into a wound made in the fleſh. But, it is poſſible for the Frog and Toad to infect plants with their venom, for I have more than once obſerved thoſe animals, when irritated, eject a kind of water, in a ſtream, from their poſteriors, which water poſſeſſes an extraordinary corroſive acrimony. This property was firſt experienced here, by a reſpectable perſon, who, in fiſhing for Jack, uſed young frogs for a bait; and once, while he was fixing a frog to his hook, the animal on a ſudden ſcattered a little of this liquor into his eye, which produced an excruciating pain in the part.

I have often taken notice of a large dog, who was very eager in the purſuit of mice, which he would ſwallow whole, without chewing. He was alſo very fond of hunting frogs and toads, and, when he had killed them, by biting, he uſed to throw them away; but at thoſe times his mouth was entirely covered with froth or foam, which I attributed to the liquor emitted by them. This was moſt particularly the caſe,

when he caught a toad, for then, he appeared almoſt mad, violently ſhaking his head, and, great quantities of froth or ſlaver iſſuing out of his mouth; but he was accuſtomed, before he began to bite the toads, repeatedly to take them in his mouth, and daſh them againſt the ground.

This virulent liquid in frogs and toads, they do not, in my opinion, emit, except upon extraordinary occaſions, when they are irritated, for it is a natural inſtinct in all animals, carefully to preſerve that, which Nature has given them for their defence. So the Scorpion, whoſe weapon of defence is his ſting, does, while creeping or running along, carry the point of the ſting turned inward, towards his body, in order to preſerve it from injury.

This ſagacity, and the other faculties we obſerve in animals, cannot be ſuppoſed to be produced ſpontaneouſly, nor that, with the creature it is bred from corruption or putrefaction, but, we ought to lay it down as a certain poſition, that theſe faculties implanted in animals, at the Beginning, have been, by a conſtant ſucceſſion, tranſmitted to their offſpring; foraſmuch as we are not to ſuppoſe that any new animal, or ſpecies of animals, is created at this day. In a word, the make and ſtructure of every creature, and the powers implanted in it, muſt, in my judgment, be aſcribed to God alone, the Creator of the Univerſe.

On Wheat, and the manner of its vegetation; the nature of the ſeveral component parts of that grain explained, and their figures deſcribed as ſeen by the microſcope.

ALL ſeeds contain in them the rudiments, or firſt beginning plants, of their reſpective ſpecies; that is, the part which, in the progreſs of vegetation, ſhoots upwards, and forms the ſtalk or ſtem, and that, which penetrates downwards into the earth, and is called the root. Seeds do alſo, for the moſt part, contain a farinaceous or mealy ſubſtance, which affords nouriſhment to the young plants until the roots are of a ſufficient ſize for extracting ſupplies from the earth, to continue and perfect their growth.

Among many other ſeeds, I have particularly examined the grains of Wheat; and, in them, the young plant I have mentioned, before it began to vegetate, having firſt either put them in water for a ſhort time, or held a few grains in my mouth, merely to moiſten the outward membranes, whereby they could the eaſier be taken off. And, having ſeparated the two external membranes which cover the young plant, I took it out from the grain, and placed it before the microſcope, when it appeared to me to be compoſed of nothing elſe than a collection of aſcending veſſels, with ſome flexures or bendings in them, and ſome minute tubercles or pimples, which pimples I conceived to be only cauſed by the evaporating of the moiſture.

In Plate VI. *fig.* 1, ABCDEF, is the whole of this begin-

original plant. And this, I take to be a certain truth, which prevails not only in plants, but in all living creatures whatſoever.

I was deſirous to examine, whether in the vegetation of corn, there would be as great a number of radicles proceed from the firſt root, as I had obſerved in graſs, and for this purpoſe, I took a glaſs tube, about half an inch in diameter, and three inches long; having ſtopped this at one end, I filled it rather more than two third parts with dry ſand, which I moiſtened with rain water, and preſſed it gently together to keep it in its place, and then depoſited it in three grains of Wheat, ſtopping alſo the other end.

This glaſs tube I frequently carried in my pocket, and in three or four days, the Wheat began to put forth roots. On the ſeventh day, the roots were ſo far grown, that I could moſt plainly diſcern them to be compoſed of wonderfully minute tubes, each of which was formed with joints, as are to be ſeen in reeds or ſtraws.

The diameter of theſe roots was, as near as I could compute, about the ſixtieth part of an inch, and, at the extremities, they were obtuſe or rounding, like the ends of thoſe quills which are taken out of the wings of birds: the ſurface of them was very ſmooth and ſhining, without any appearance of radicles iſſuing from them, excepting near the grain, where numbers of exquiſitely minute radicles were to be ſeen.

On the eighth day, the young germ or ſhoot had grown to the length of three quarters of an inch, the roots were alſo ſo far grown as to reach the bottom of the tube, whereupon I took out the cork, and they then protruded themſelves out of the tube, and I hoped to have diſcovered in them, whether there were the ſame joints in the ſmall radicles as in the larger roots; but, in the ſpace of half a minute, the moiſture in them was ſo evaporated, that they became contracted into irregular ſhapes.

With regard to the ſize of theſe exceſſively minute radicles, I made the following eſtimate, as far as my eye could judge. Suppoſing the diameter of them to be as 1, that of the larger root from which they proceeded muſt be conſidered as 20, and conſequently, 400 of theſe ſlender radicles taken together were equal to the ſize of the larger root. Now, the diameter of this larger root being, as before obſerved, the ſixtieth part of an inch, 3600 of thoſe roots will be equal to a cylinder of an inch diameter; and if this number be multiplied by 400, it follows, that 1,440,000 of the ſmalleſt radicles are altogether equal to a cylinder the ſize of an inch.

This being the caſe, we may naturally conclude, that when any plant is pulled up by the roots, ſuch ſlender radicles as theſe, not only eſcape our ſight, but muſt almoſt all be broken off, unleſs the earth or moiſt ſand which ſurrounds them adhere to, or is taken up with them.

After theſe very ſlender radicles I have deſcribed, had remained in the tube three or four days, thoſe parts of them which did not touch either the ſand or the glaſs, and were expoſed only to the air within the cavity, were ſo dried up and contracted into irregular forms, that they appeared like parcels of wool, or the threads of fine linen tangled together.

In the month of April, I took up in a field, which in the preceding autumn had been ſown with Wheat, ſome of the young blades or ſhoots, with their roots, and the earth adhering to them: and upon examining theſe, I obſerved nothing viſible, except the largeſt ſhoot or parent plant, which was by far the largeſt, and had ſhot up much the higheſt. To ſhew the ſize of this plant, I cauſed a drawing to be made of it, which is to be ſeen at *fig.* 7, WXYZ; and in this plant the blade being ſhot up to the height of about four inches, the joints, or knots in the ſtalk, were already formed, the young ear lying at the end next to the root, at W.

This plant, repreſented at *fig.* 7, I cut open, and took in pieces, until I perceived the ſmalleſt leaves of all, which as I may ſay, ſurrounded the ear; theſe alſo I took off, and then the ear itſelf was viſible, which, viewed through the microſcope, appeared as at *fig.* 8, ABCDE. But, I did not deliver this Object to the Limner, until I had diſſected ſeveral of the young plants, and found, that they were all exactly of the ſame figure.

At the expiration of nine days from this time, I examined more of the young blades of Wheat, but did not perceive any change in the ear worthy of note, except that it was grown ſomewhat higher from the root, and that the joints or knots in the ſtalk, were more plainly to be diſtinguiſhed.

The ſtems or ſtalks of Wheat, which, after the grain has been threſhed out from the ear, are denominated Straw, appear to the eye wonderfully ſmooth and ſhining, the outer coat of them being compoſed for the greater part, of veſſels incredibly ſlender, with here and there a few larger ones intermixed; the inner part is compoſed of larger veſſels, all which I have repreſented as nearly as poſſible to Nature, in the following figure.

Fig. 9, ABCDEF is a very ſmall piece of Straw, cut tranſverſely, and ſeen through the microſcope: any perſon, by conſidering what proportion the arch, or curved external part of it, marked AF, bears to a circle, and, comparing the ſame with ſo much of the known diameter of a Straw, may eaſily conceive the natural ſize of the particle here repreſented.

ABEF, is the bark or outer coat, compoſed of the veſſels before deſcribed; GGGG, are the veſſels of which the inner part for the moſt part conſiſts; they are of four, five, and ſix ſides, according as, at their firſt formation, their ſhape is accommodated to thoſe adjoining them.

HHHH, are veſſels intermixed with the laſt mentioned ones, and

containing in them ſtill ſmaller veſſels; in theſe veſſels I have ſeen the juices (at the time the Wheat ſtalks are growing) running with a wonderfully rapid courſe; and, through the joints or valves in thoſe veſſels marked G, the juice was carried upwards, which juice was for the greateſt part compoſed of globules; and when theſe globules came to paſs the valves where the paſſage through the veſſels is very narrow, they aſſumed an oblong figure, until they came into a larger ſpace, when they reaſſumed their priſtine globular ſhape.

Fig. 10 repreſents theſe aſcending veſſels cut longitudinally, and ſeen through the microſcope, being the ſame which in *fig.* 9, are marked G G: at I I, are the valves I have mentioned, and, in thoſe parts, the paſſages through the veſſels are the moſt narrow or confined of all.

The ſtalks of Wheat, are formed of none other than perpendicular or aſcending veſſels, and that, in my judgment, is the reaſon, why they are furniſhed with a kind of joints or knots, at certain intervals, in order to give ſtrength to them; and that, without ſuch joints, the ſtalk would not be able to ſupport the ear, which is its fruit. This is alſo the caſe with graſſes, and likewiſe with reeds, for the ſame reaſon; and it alſo obtains in the bodies of ſome trees. In theſe northern parts, indeed, all trees are provided with horizontal veſſels, whereby they have a ſufficient ſtrength; but, in the warmer climates, where many of the trees have no other than perpendicular veſſels, ſuch as is the cocoa-nut tree, the want of horizontal veſſels is compenſated, by numbers of theſe kind of joints, formed at ſhort intervals, through the whole length of the tree.

The farinaceous or mealy part, of which the grains of Wheat are principally compoſed, conſiſts of thoſe minute globules I have before noticed. Theſe globules are, ſingly, tranſparent, and lie cloſely compacted within a kind of membranes, ſo exquiſitely thin and tranſ-

parent, that, in ſome places, their texture is not to be diſcerned. A very ſmall particle of one of theſe membranes, as it appeared upon the grain being cut longitudinally, is ſhewn at *fig.* 11, EFGH; within theſe membranes the globules of meal are incloſed, as it were, in cells; and, at H, ſome of thoſe cells are repreſented, filled with the globules of meal: the natural ſize of this figure, is no more than can be covered by a common grain of ſand.

The globules of meal, are of very different ſizes, ſome being more than an hundred times larger than others, and ſome ſo ſmall, that they almoſt eſcape the view of the microſcope. In order to give the reader ſome general idea of their minuteneſs, I took one of the larger grains of that ſort of pellucid ſand, uſed in ſcowering or grinding; this grain of ſand, together with ſome of the globules of meal adhering to it, I cauſed to be drawn from the microſcope, as at *fig.* 12, ABCDE. In the ſame figure, FGH denote a ſmaller grain of ſand adjoining to the former. IKLM are ſome of the larger and ſmaller globules of meal, lying near the grains of ſand.

I had at firſt imagined theſe mealy particles to be quite globular, but I afterwards found, that I had been miſtaken in that reſpect; and that they were not perfect ſpheres, each of them having a kind of creaſe, chink, or indenting, like that which we ſee in the grains of Wheat, which had at firſt eſcaped my notice, partly from the extreme minuteneſs of the particles themſelves, and partly from their different poſitions with reſpect to the eye.

Upon viewing theſe mealy particles, and the indentings in them I have mentioned, I began, not without wonder, thus to reaſon with myſelf. Certainly theſe particles of meal were not compoſed by a concretion or collection of ſtill ſmaller particles, placed ſide by ſide, as is obſerved in ſome liquors, ſuch as wine and beer, whoſe particles coagulate, and grow together in maſſes, which, in the former we call dregs, and, in the lattertartar; but the particles of meal muſt be formed

in another manner, that is, not by coagulation, but by growth. And the membranes which incloſe them in cells, muſt be provided with ſo many veins or veſſels, that every particle of meal may have its ſeparate vein, whence it derives its ſubſtance and increaſe, in like manner as the eggs of fiſhes are nouriſhed by a ligament or veſſel, which is obſerved not only in the larger fiſh, but in thoſe very minute eggs which are ſeen in vaſt numbers on ſhrimps. Now, if the particles of meal, which, though not ſtrictly ſpherical, may yet be termed globules, had not acquired their growth in that manner, it ſhould ſeem that they could not obtain that globular figure.

When we conſider the tranſparency of every one of theſe globules of meal, we may well exclaim, How wonderful is this formation, and how cloſely compacted muſt be the ſmalleſt particles of which each globule is compoſed, to give it that tranſparency!

I next proceeded to examine, whether theſe particles of meal might not be globules, incloſed in a certain thin membrane, as we ſee is the caſe with all ſeeds; but I cannot be confident, that I ever did bring this to my ocular demonſtration. I then broke the globules in pieces, and imagined that I ſaw ſmaller ones incloſed in them, but herein I found myſelf miſtaken, for, thoſe globules which I ſaw ſcattered among the pieces, were ſome of the very ſmalleſt mealy globules, collected in ſmall parcels.

I then uſed my utmoſt endeavours, to diſcover the internal hidden make of the globules of meal, wherein, at length, to my great ſatisfaction, I ſucceeded. I placed ſome of them on a clean glaſs, and mixed them with a very ſmall drop of water: when they were by this means ſeparated, I poured on them two more drops of water, and brought the glaſs ſo near to the fire, that in the ſpace of a minute, the water was all evaporated. Then, bringing them before the microſcope, I perceived, that their globular form was changed into flat ſhapes, of different ſizes, according to the different magnitudes of the

globules themſelves. Many of them had a little riſing in the middle, which I judged to be that part, through which they had received their growth and increaſe.

This convinced me, that the globules of meal in Wheat, are covered with a ſkin or ſhell, in like manner as the Wheat itſelf, for, by the compreſſion and flattening of the figures in the above experiment, they would have been diſſolved or ſeparated, had they not been confined by ſome ſuch covering. I then concluded, that the chinks, creaſes, or indentings I have noted in theſe globules, were in thoſe parts where their ſkins had a kind of ſeam or joining, ſo that when warmed and moiſtened, their ſkins had burſt open at thoſe places, and the globules ſubſided into a flat ſhape, as before mentioned.

From this obſervation, I was induced to examine the grains of Wheat themſelves, in order to inveſtigate, how, and for what purpoſe they were formed with thoſe indentings, chinks, or creaſes.

For this purpoſe, I cut pieces off the grains, by a tranſverſe ſection, and examined thoſe pieces by the microſcope, when I found, that the ſhell or huſk takes its courſe into the middle of the grain, and, on each ſide, returns in a curve or bending to the chink, by which means, the huſk, when the grain ſwells upon being moiſtened, can expand itſelf into a greater ſpace.

Hereupon I was led to conſider, that, whereas fowls, turkies, partridges, pigeons, and other birds who feed on corn, cannot with their bills, break or grind the grains of Wheat, Rye, and Barley, but take them into their ſtomachs entire, where, by reaſon of the hardneſs of the huſks, they cannot be broken; ſeeing this, I ſay, I conſidered, that theſe kinds of grain muſt have been ſo contrived and formed by the all-wiſe Creator, that, without the huſks being broken in pieces and digeſted, their contents may be diſſolved: which is thus performed, namely, that by the moiſture and heat in the ſtomachs of

thoſe animals, the outward huſks, or ſhells, may be expanded and burſt open, and the meal which they contain, having by this means a paſſage opened to quit its covering, may be diſſolved, digeſted, and converted into nutriment.

To inveſtigate this more fully, I took a glaſs tube, about the ſize of a finger, and cloſed at one end; into this I put ſome grains of Wheat and Barley, with a ſufficient quantity of water, and then applied ſo much heat to it, as, in a ſhort time, made the water boil. Then, upon examining the Wheat and Barley, I obſerved, that their huſks, which before, had been as it were cloſely folded or cloſed together, were not now, broken or torn aſunder, but, in the places where the grains had been contracted and turned inwards, the parts had now receded either way, cauſing the huſk to gape open, ſo that, in ſome of the grains, a part of the meal was viſible, and in others the whole contents were laid open. Some of the grains of Wheat, however, I obſerved, which had ſwelled to three times their original ſize, the huſks remaining entire.

After this, I examined the dung of ſome hens, which, in the time of a deep ſnow, were kept ſhut up in a coop, and fed with nothing but barley, which, it is well known, they ſwallow whole. And, in the dung of theſe fowls, I was much ſurprized to find nothing obſervable, except a great number of pieces of the huſks of barley; and I was at a loſs to comprehend, how ſo great a quantity of meal as thoſe huſks had contained, could have entered into the bodies of theſe fowls, conſidering that they were all full grown.

Farther, I inſpected the dung of many ſparrows, in which I found a great number of very ſmall hairs, cloſely compacted together, in a kind of regular order; together with many fragments of the huſks of Wheat and Barley. I at firſt wondered what theſe hairs might be, till I recollected the hairy or reed-like parts at the extremities of the grains of corn, which I have before deſcribed, and found theſe to be

the ſame, for, in them I could perceive a kind of ſtreak or hollow, which is obſervable on thoſe hairs. Theſe ſparrows, I underſtood, during this ſeaſon, when the ground was every where covered with ſnow, ſought their food in the corn market, where they picked up the grains which, in handling and viewing the corn, had fallen to the ground.

In order to exhibit to the eye, the manner in which the huſks of Wheat are folded or cloſed together, I cauſed a drawing to be made from the microſcope, of a piece cut from the grain tranſverſely; but firſt, to ſhew the poſition of the chink or indenting, I ordered the limner to draw a figure of the entire grain, in its natural ſize. This is ſhewn at *fig.* 14, wherein the fiſſure, chink, or indenting, is denoted by the letters N O. The line P Q, indicates the part from which, with a very ſharp knife, I cut ſeveral ſlices.

Fig. 15, A B C D E, repreſents a part or ſlice of the huſk of Wheat, incloſing the meal, cut off as above mentioned, and viewed through the microſcope. A, is the part near that place in the grain, where the young plant is ſituated. G H F K I, are the two bendings inwards of the huſk, in a kind of circular courſe, the intent of which formation doubtleſs is, that, when the grain ſwells upon being moiſtened, the huſk may expand itſelf, and ſtill preſerve the meal in its place: and by inſpection of the part F, it will be ſeen, that the huſk is not cloſely united where the two bendings or flexures meet, to the end, that when the meal expands itſelf ſtill more, the two ſides of the huſk may recede from each other, and produce an opening at that place.

I have already deſcribed the ſize of the globules of meal, by compariſon with larger and ſmaller grains of ſand. I alſo cauſed ſome of theſe globules to be drawn, as ſeen through a microſcope of very great magnifying power; firſt, to ſhew more diſtinctly that they are formed with a chink or crevice on them, next to exhibit to view the

ſmaller globules, mixed with the larger, and finally, how the chink or crevice appears on them. Theſe are ſhewn at *fig.* 16, LMNOP QR.

I have frequently repeated the experiment of placing a portion of theſe globules of meal, no larger than a grain of ſand, upon a clean glaſs; and, after pouring a drop of water on them, brought it to the fire. After the water and globules were heated, and the moiſture was evaporated, the globules aſſumed a flat ſhape, very like that of cakes, which is repreſented in *fig.* 17, STVW. Moſt of theſe had a little riſing in the middle, being the place, as I before mentioned, where, in my judgment, they were ſupplied with juices in their growth. And I have often ſeen the very ſmalleſt of the globules undergo the ſame alteration in their ſhape as the larger ones. In theſe obſervations I found a portion of meal, no larger than a grain of ſand, mixed with a ſmall drop of water, fully ſufficient to exhibit the change of ſhape before noted; for, if more of the meal is uſed, the particles lie ſo confuſedly heaped on one another, that they cannot be diſtinctly ſeen, and, it is ſcarcely to be conceived, that a portion of meal, no larger than a grain of ſand, ſhould conſiſt of ſo many particles as are pictured in *fig.* 17.

I have often examined a ſmall piece of bread, taken from a loaf made of fine flour, after the huſk or bran had been taken from it. The particles of meal in this ſmall piece of bread, appeared very much like thoſe repreſented in *fig.* 17, with this difference only, that the particles in the bread, lay much more irregularly, and appeared more mis-ſhapen, with ragged points and riſings; a true repreſentation of all which is to be ſeen at *fig.* 18, ABCDE.

ADDITION, BY THE TRANSLATOR.

WHOEVER peruſes Mr. Leeuwenhoek's Works, will find diſplayed in them much ſound philoſophical knowledge, of which ſome inſtances appear in the preceding Eſſay. Theſe I ſhall quote, in order to explain tho ſeparts in them, which may appear difficult to ſome of my readers. In page 171, the author tells us, that the ſubſtance incloſing the young plants of Wheat, appears of a different colour from the mealy part of the grain, by reaſon that the globules which compoſe it are not, ſingly, ſo pellucid, and therefore do not, altogether, appear ſo white, as the meal; and in p. 179 he reflects, with admiration, how cloſely compacted muſt be the ſmalleſt component particles of the globules of meal, to give them that tranſparency. To thoſe, who are not converſant in optics, it may appear ſtrange, that the moſt tranſparent bodies have the ſmalleſt pores, and, that a collection of ſmall tranſparent globules ſhould altogether exhibit a white colour, but this is according to the eſtabliſhed doctrine of light and colours, of which Mr. Leeuwenhoek appears to have been fully informed.

As to the firſt, Sir Iſaac Newton has ſhewn, that it is not the largeneſs of the pores of bodies which makes them tranſparent, but the equal denſity or continuity of their parts; which, he ſays, appears from hence, that all opake bodies immediately begin to be tranſparent, when their pores become filled with a ſubſtance of equal or almoſt equal denſity, with their parts: thus paper, dipped in water or oil, linen cloth ſteeped in oil or vinegar; and other ſubſtances, ſoaked in ſuch fluids as will intimately pervade their little pores, become more tranſparent than before.

As to the ſecond, white being a compoſition of all colours, a collection of tranſparent globules, which, from their ſurfaces reflect the light in all directions, will produce whiteneſs by that reflection. This is ſeen in the froth on liquids, and particularly ſoap-ſuds, which is nothing but a compoſition of minute globules of water, made tenacious by the ſoap.

Of the Cocoa Tree, and its Fruit, commonly called the Cocoa-nut.

I HAVE ſaid, that ſtraws, reeds, and many other ſtalks of plants, were formed of none other than perpendicular veſſels, whereas the ſtems or bodies of all trees growing in our climate, at leaſt as far as I have ever underſtood, are likewiſe provided with horizontal veſſels; the uſe of ſuch laſt mentioned veſſels being, in my judgment, to convey the nutritive juices to the exterior parts of the tree. Now theſe horizontal veſſels impart ſuch ſtrength and firmneſs to the timber or trunk, that the moſt ſpreading trees are enabled to reſiſt the violence of the wind.

But ſtraws, reeds, and other ſtalks which are deſtitute of horizontal veſſels, require ſome other means of ſupport; for, if all the veſſels, from the earth up to the ſummit of the ſtalk, were diſpoſed only in uninterrupted parallel lines, the ſtalks would be ſo weak and flexible, that they could neither reſiſt the wind, nor be able even to bear the weight of their own fruit. Therefore, theſe kinds of ſtalks, are ſtrengthened by a ſort of joints or knots, at intervals, which prevent the over much bending of the ſtalk; and the joints are placed at ſuch diſtances that the ſpaces between each will allow the bending, only ſo much as to recover itſelf.

What has been ſaid of the joints in ſtalks growing in theſe regions, I conſider as applicable to ſome ſorts of trees in the Indies; and, upon ſeeing ſome of thoſe Indian trees deſcribed in drawings, I immediately concluded, that the Cocoa Tree was of the number.

After ſeveral endeavours to obtain a ſpecimen of this tree, I at length

procured from a certain ſea captain, a piece of one, about a foot long, and ten inches in diameter. The bark of this wood was found, but the wood itſelf ſo decayed, that it crumbled into powder under the fingers, excepting only a very ſmall part. The capillary or hairy parts which run lengthwiſe on the inſide of the bark, were tolerably ſound, but they ſeparated from each other, as eaſily as if they had never been firmly united, which made me ſuſpect, that, if there ever had been any other parts to connect them, they were decayed.

I perceived that theſe capillary or hairy parts, grew out of the bark, and that many of them were divided into two; and I alſo perceived in each of theſe capillaments many veſſels. Among theſe capillary parts were others, ſome firm and ſolid, others in the nature of veſſels, but the greater part of them much decayed.

Theſe capillary parts, were covered by the external ſolid bark, which bark was, in ſome few places, thicker than in others, but, at the knots or joints, the bark was remarkably thick and ſolid.

This bark, cut tranſverſely, I examined by the microſcope, and found it chiefly to conſiſt of roundiſh threads, about the thickneſs of an hair, and theſe again compoſed of oblong filaments, hollowed on the inſides. Many of theſe latter did not take a ſtraight, perpendicular courſe, but turned inwards towards the body of the tree. Farther, I obſerved, intermixed among them, a kind of ſubſtance, conſiſting of roundiſh globules, connected in a ſort of regular order. Theſe parts, compoſing the external ſubſtance of the tree, were ſo cloſely united together, that it might be thought the tree had not any bark on it. From all theſe obſervations, I was led to conclude, that this tree receives its growth and increaſe from the bark alone. And I perceived certain roundiſh parts, which ſeemed to iſſue in a right line from the bark inwards, as if they were deſigned for no other uſe, than to convey the nutritive juices in that direction.

If, however, we could be furniſhed with a piece of this tree, cut while alive and growing, our obſervations might be much more accurate. And, indeed, I was not without ſuſpicion that this piece of wood had been cut from a dead tree, though one of the ſeamen aſſured me, that the decay which I have before mentioned, happened to it on board the ſhip.

In order to place before the reader's eye the form of the joints knots, or bands, whereby the body of the Cocoa-tree is ſtrengthened, and which as it were, ſurround it throughout with a ſort of girdle, I cauſed a drawing to be made of this piece of wood, on a contracted ſcale; from which drawing will be ſeen, how firmly thoſe trees, which have no horizontal veſſels, are ſtrengthened by theſe kind of bands, ſurrounding them in an oblique direction.

In Plate VII. *fig.* 1, A B C D E F G H I K L M, repreſent this wood drawn ſmaller than the natural ſize. C M, C L, D L, E K, F K, F I, indicate the poſition and courſe of the knots or bands, that is, that they do not go in a ſtraight line round the tree, but ſometimes approach to, and ſometimes recede from, each other, which approach and receding are ſhown at K L. And, this oblique courſe of the knots, bands, or cinctures, contributes more to the ſtrength of the tree, than if they encircled it in the form of hoops.

By cutting and examining this wood, in the manner I have deſcribed, I fully ſatisfied myſelf in the particular wherein I wiſhed to be aſcertained, namely, that the Cocoa Tree has no horizontal veſſels. And there is moreover a circumſtance to be noted in theſe kinds of trees, that they have no branches except at the very tops, and therefore, are not ſo ſtrongly acted upon by the force of the wind. Nor are the branches which they have, perennial, but they every year fall off, and are replaced by freſh branches, which grow on the tree at the ſame time with the fruit.

I alſo cut tranſverſely a piece of the wood, in a part where it was

ſound, in order to ſhew, as accurately as poſſible, the make and texture of this wood, when viewed by the microſcope.

Fig. 2, O P Q R, repreſents a very ſmall particle of the Cocoa wood, cut tranſverſely, and magnified, wherein are to be ſeen ſix of the larger of the perpendicular veſſels, two of which, ſurrounded by a great number of ſmaller veſſels, are to be ſeen at T T. Of theſe larger and ſmaller veſſels, the capillary or hairy parts I have mentioned, and which are very tough and ſtrong, are compoſed. But theſe veſſels do not all aſcend in an exact perpendicular direction, but creep upwards in a kind of oblique courſe, one among another, by which poſition they contribute to the ſtrength of the tree. And when one of theſe veſſels or threads divides itſelf, each divided part, though it preſents the figure of a ſmaller filament, is yet in truth a perfect veſſel. Theſe ſmaller veſſels, intermixed with the larger ones, I have cauſed to be repreſented in the drawing.

Theſe larger veſſels ſeem connected together by a kind of veſicles, which, I imagine, while the tree is alive and flouriſhing, are filled with ſome kind of liquid. Theſe veſicles are not diſpoſed in any orderly or proportionate manner, but in ſome places they may be ſeen heaped together to the number of five and twenty, and in other places, between two capillaments, will be found only a ſingle veſicle.

Such of theſe capillaments as are next to the bark of the tree, are exceeding ſmall, in compariſon of thoſe nearer the middle; and, to exhibit them to the reader, I cut off a piece of the wood next to the bark, and cauſed it to be drawn from the microſcope, which drawing is copied at *fig.* 3, A B C D. In this figure, A D is an innermoſt bark next the wood, being a very thin ſkin, and the capillaments next to it are the ſmalleſt of all, whereas thoſe more inwards, grow larger and larger. But, though theſe innermoſt cappillaments are the largeſt, they are ſtill compoſed of thoſe exquiſitely

thin and hollow filaments I have mentioned, the hollows or cavities in which I have cauſed to be repreſented by a ſort of points or dots. The black ſhade in this figure, denotes minute veſſels ſurrounding the others, which by reaſon of their exceeding ſmallneſs could not be repreſented in the drawing.

Theſe veſicles, which I have mentioned to adhere to the capillaments, as they appear, when cut by a ſtraight ſection, are ſhewn at *fig.* 4, E F G H. In theſe veſicles there appeared ſome ſmall particles, concerning which, however, I could not pronounce any thing with certainty.

After I had made the preceding obſervations, I received from a friend who obſerved how deſirous I was to inveſtigate the nature of the Cocoa wood, a piece of that wood which he had procured from the iſland of Curaçoa. This was ſeven inches in diameter, and about four inches long: in the middle, it was compoſed of the before mentioned larger capillary parts, but, on the outſide, and about an inch from the ſurface, it was ſo hard, that in attempting to ſplit it, I broke a ſteel wedge in pieces, and I do not remember ever to have met with ſo hard a wood.

Between the bark and the ſolid part of this wood, I ſaw ſome capillary parts creeping along, and which were of the ſame nature as thoſe pictured in *fig.* 1, between G and N, and theſe capillaments, I was informed, are made uſe of to be twiſted into ropes and cables.

I obſerved, that wherever the knots or bands in the bark approached each other, as at F K, there the capillaments grew out of the bark: ſometimes I obſerved one or two branches riſe out of one of theſe capillaments, and theſe again ſubdivide into ſmaller ones, hollow within, and which capillaments I judged might in time unite and form veſſels of the ſize pictured in *fig.* 2, at T T. And if ſo, it follows that the Cocoa tree receives the addition to its bulk from the

bark, contrary to what we ſee in the trees of this country, the bark of which receives its increaſe from the wood.

I alſo cut this wood from Curaçoa tranſverſely, and examining it by the microſcope, I found it to agree in all reſpects with that repreſented in *fig.* 2, with this difference only, that where this wood was harder than the former, there the capillaments were ſmaller, and alſo exceedingly tough.

But as the veſicles in the former wood, which are repreſented at *fig.* 4, EFGH, were in this latter much harder, and alſo ſmaller than the former, I cut ſome of them by a ſtraight ſection, and cauſed a very ſmall particle of them, when magnified, to be drawn from the microſcope, which is to be ſeen in *fig.* 5, at 3 L M 2. Theſe veſicles, I perceived were of a more firm and ſolid texture, than thoſe in the other piece of wood, and they had in their centers a black ſpot, which was a ſign that they had had a cavity in them: ſome of theſe veſicles I cut in ſuch thin ſlices that they appeared tranſparent.

While I was buſied in this part of my inveſtigation, I happened to cut one of the aſcending veſſels, which in *fig.* 2, is denoted by T, but which here is ſhewn between I K 3 2 N. And, though the ſmaller veſſels ſurrounding it, could not, by reaſon of their minuteneſs, be otherwiſe expreſſed, than by ſtraight lines, yet this larger veſſel plainly appeared to be formed of a kind of annular parts, running round each other in a ſort of ſpiral form. And, though I had obſerved this formation of the veſſels in many other ſorts of wood, yet I could not till now, venture to ſay, that theſe veſſels were formed in that manner, becauſe I had hitherto loſt my time and labour in endeavouring to diſſect them accurately. But now in this object, where the veſſel ſpread or opened itſelf a little, at the place marked N, I plainly ſaw the ſpiral formation, which diſcovery gave me great pleaſure.

I proceeded ſtill farther in the examination of this larger veſſel, and I found it to be compoſed of, at leaſt, five ſmaller ones, which were placed in regular order, beſide each other, and each ſeverally formed in the ſpiral manner I have mentioned. All theſe are ſhewn in *fig.* 6, O P, and in the ſame figure, at P Q, is to be ſeen the part which I before mentioned having ſeen, as deſcribed in *fig.* 5, at N.

This circuitous figure of the veſſels, may be exactly compared to a braſs wire, twiſted round a ſmall rod, and the ſame kind of formation I have frequently, as I have before mentioned, ſeen in other woods. And even in a ſtraw I once obſerved, by the microſcope, one of its larger veſſels to be formed, much in the ſame manner as this I have deſcribed at O P. And, when we conſider the ſubject, we cannot, in my humble opinion, conceive any form ſo ſuitable for thoſe veſſels to raiſe the juices upwards.

The ſame gentleman from whom I received the laſt mentioned piece of Cocoa wood, ſent me alſo two Cocoa nuts, incloſed in their ſeveral ſhells or coverings. From one of theſe I cut ſo much of the outer covering, as to exhibit the inner ſhell to view; and I cauſed a drawing to be made of both, on a contracted ſcale, which is to be ſeen at *fig.* 7, A B C D. The diameter of this external caſe or covering was nearly five inches and three quarters, meaſured by the ſcale B D, which is five inches long.

This external huſk or ſhell ſo firmly adhered to the inner one, being connected to it by multitudes of veſſels, that I found it a work of conſiderable labour, to tear it off. The inner ſhell was four inches in diameter, and, having cleared it from all the veſſels adhering to it, I replaced it in the half of the caſe or huſk, as is to be ſeen in the drawing.

I have often been told, that the filaments of which this external huſk or bark conſiſts, are of ſuch a length that they are twiſted into cables, and alſo wove into ſail-cloth. I proceeded, therefore, to exa-

mine the texture of this huſk or bark, when I found, that not a tenth part of it conſiſted of thoſe filaments, but that, from them proceeded a certain ſubſtance, like a collection of veſicles, which veſicles, while the fruit was living on the tree, had been filled with juices, in like manner as thoſe parts which, collected in great numbers, from the ſubſtance of the pear called the Sugar pear, do proceed from the veins or veſſels in that pear.

To convey a true idea of the formation of this external coat, huſk, or covering, of the Cocoa-nut, I cauſed a drawing to be made from the microſcope of a very ſmall piece of it, as is to be ſeen in *fig.* 8, M N O P Q. Here, N P Q denote the capillaments, which may more properly be called veſſels; they are each incloſed in a larger one, which larger one is compoſed of numbers of minute veſſels.

It is well known, that all fruits, and even the ſmalleſt leaves, are covered with a ſkin, which, that it may prevent the exhalation of the juices, is of a very cloſe texture. This external coat or huſk of the Cocoa-nut has that kind of ſkin, which, as it appears through the microſcope, is exhibited in *fig.* 9, A B C D E F G H, where are ſhewn as exactly as may be, the veſſels running along this ſkin, and connected with the internal part of the huſk, as for example, as B D E, A E, and H G. A branch proceeding from the veſſel B E, is repreſented at C D.

In the ſhell of the nut, pictured at *fig.* 7, there are three parts ſomewhat reſembling eyes, two of which point towards each other, the third contains the young plant, which, when the kernel begins to vegetate, ſhoots out through that cavity. And this young plant in its vegetation receives nouriſhment from the kernel, through theſe perforations I have called eyes, until it is able to draw its nouriſhment from the earth, and this, without there being a neceſſity for the ſhell of the nut to break or open. The vegetation of the

cheſnut is performed in the ſame way, contrary to what is obſerved in the ſeeds of nuts, plumbs, and the like, the ſhells of which, as the vegetation of the kernel advances, divide and open themſelves.

Moreover, I cut off ſeveral pieces from the hard ſhell of the Cocoa-nut, ſome of them longitudinally, ſome tranſverſely, in order to ſhew the texture of it, as ſeen by the microſcope, This is repreſented at *fig.* 10, I K L M N, in the inner part of which is a vein or veſſel dividing itſelf into many ſmaller ones.

I next proceeded to examine a thin membrane or ſkin, which lines the inſide of this hard ſhell. An incredible number of veſſels which may be ſeen by the naked eye, are diſperſed through this membrane; the hard ſhell is of a dark colour, verging towards a black, and the membrane of a faint aſh colour. I have often placed pieces of this membrane before the microſcope, and could not, without admiration, behold the almoſt incredible number of ſmall oblong parts therein, which were heaped one on another, in ſuch various manners that I could not conjecture for what uſe they were deſigned; but they all conſiſted of ſpiral parts, ſuch as are deſcribed in *fig.* 6, at O P. Theſe parts were ſo exquiſitely ſlender, that upon comparing them with a vein taken from the breaſt of a flea, which I had ſtanding before a microſcope, I found that the vein (which was alſo of a ſpiral form) was about four times as large as theſe component parts of the membrane, and I could not ſufficiently wonder at the multitude of thoſe ſpiral parts.

I have alſo often placed before the microſcope, thoſe capillaments which in breaking the ſhell I found adhering to it by one of their extremities, merely for the pleaſure of contemplating the object; for, a capillament no larger than an hair, would be ſeen to conſiſt of twenty filaments, the ſmalleſt of which I judged to be leſs than the thread ſpun by the ſilk worm. So that, if we would compute the whole

number of theſe filaments in a ſingle nut, we muſt not reckon them by thouſands, but by hundreds of thouſands.

That which is the kernel of this nut, and is commonly called the Cocoa-nut, is a very white ſubſtance, about half an inch thick, cloſely joined to the whole interior part of the ſhell; the remainder of the cavity contains a watery juice, which is what I never obſerved in any other ſeed, when come to maturity. For nuts and cheſnuts are entirely compoſed of ſolid parts, which we call the kernel, though before they come to maturity the matter incloſed in them is no more than a watery and ſlimy ſubſtance.

Upon this head, I reaſoned with myſelf; that before the inward ſubſtance of the Cocoa-nut is full grown and ripe, the ſhell becomes harder than thoſe of any fruit known in the northern climates; and I concluded that when the ſhell is grown perfectly hard, it cannot be afterwards increaſed in ſize, nor can the kernel it contains receive any addition to its ſubſtance: and therefore, that part of the nutritive juice which is of a watery nature, and cannot be converted into kernel, muſt remain in the center of the nut.

I afterwards fell into converſation with two maſters of ſhips, who had viſited both the Eaſt and Weſt Indies, and had been often employed in collecting Cocoa-nuts. They informed me, that when the ſhells of the nuts were ſo ſoft that they could be cut with a knife, there was nothing to be found in them except a lymph, or thin liquor, of a very pleaſant taſte, which information confirmed me in the opinion I have before related.

At another time, upon a different inveſtigation of the Cocoa-nut, I preſſed from the pulp or white ſubſtance of it, ſuch a quantity of oil as fixed me in aſtoniſhment.

After this, upon opening a Cocoa-nut which I had kept for the ſpace of ſeven months in my cabinet, I obſerved thoſe three ſoft places in the ſhell which are called eyes, and from one of which the

young plant ſhoots forth, to be covered, and, as it were, ſealed up, with a ſubſtance like roſin or pitch.

To give a more perfect idea of the nature of the Cocoa-nut or kernel, after I had bored the ſhell near the place where thoſe parts I have likened to eyes are ſituated, and poured out the juice contained in the cavity, I broke away the ſhell ſo far as was ſufficient to ſhew the inſide of the nut, that it might be expreſſed in a drawing.

Fig. 11, O P Q R, repreſents the Cocoa-nut or kernel as it appears, incloſed in the ſhell, which ſhell is denoted by P Q R. At P R, are ſome of thoſe capillaments, which in great numbers, are found united to the ſhell, and, as they are in fact, no other than veſſels deſtined to convey the nutritive juices, they penetrate into the interior part of the ſhell, and there impart nouriſhment to the fruit. Farther, many very ſmall veſſels take their courſe through the hard ſhell, and theſe, as I found by the microſcope, were compoſed of other veſſels incredibly ſlender, the ſmalleſt of which were of the ſpiral formation deſcribed in *fig.* 6, O P.

S T V, denote the nut itſelf, properly ſo called. W X Y is a cavity within it, which contains the ſap or juice I have mentioned, which is very pleaſant to the taſte, and of a nouriſhing quality. A drop of this juice I put into a very clean glaſs, in order, when the watery parts of it were exhaled, to examine the remainder, and therein I did not find any ſaline particles, but it had the appearance of a ſyrup, which did not evaporate, being more of a fixed nature.

This kernel is connected with the hard ſhell by infinite numbers of veſſels, and on the ſide next the ſhell is alſo covered with a thin ſkin, through which multitudes of veſſels take their courſe; they are of the ſame ſpiral figure as before mentioned, and lye cloſe together, and they are not much thicker than the hair of a man's

beard. Whence it appears that the kernel is formed and nouriſhed from theſe very ſlender veſſels.

Upon examining this nut or kernel by the microſcope, I found that its ſubſtance is not, like other ſeeds, incloſed in ſmall membranes, but conſiſts of multitudes of minute tubes, which take their riſe from the hard ſhell, and reach to the cavity, within the kernel, where the juice I have mentioned is collected. They are not all of an equal ſize, nor are they of a round figure, but rather of ſix ſides, which ſhape is well adapted to permit their lying cloſe together and in regular order. Some of theſe are turgid with a certain ſubſtance, which in part evaporates; others of them contain globules which I judged to be chiefly filled with an oil.

Theſe ſmall tubes, which in *fig.* 11 are to be ſeen at W, I cut tranſverſely, and cauſed a drawing to be made of a very ſmall portion, as viewed by the microſcope, which in *fig.* 12 is expreſſed by *ABCD*: the ſmall points, or dots in this figure, denote ſome very ſmall particles, which I obſerved in theſe tubes.

Moreover, I cauſed a drawing to be made of that part of the nut or kernel, where I judged the young plant to be ſituated, in the ſhape it exhibits when ſeen by the eye alone, without the microſcope. This occupies but a very ſmall part of the kernel, and is ſituated in a part where its ſubſtance is thinneſt. A drawing of this, of the natural ſize, is to be ſeen at *fig.* 13, ABC D EF, and H EG is the part which in my judgment contains the entire young plant.

From this part I cut ſome very thin ſlices at that end of it which in *fig.* 13 is neareſt to the letter E. For I was deſirous to examine whether any thing would there be found bearing any ſimilitude or reſemblance in figure to the future ſtem of the tree. Some of theſe ſlices I placed before the microſcope, and cauſed a very ſmall portion thereof to be drawn, that it might not take up too much ſpace in the paper. This is repreſented in *fig.* 14, at *EFGHI.* In this

figure *IEF* denote the ſkin or covering, incloſing what I take to be the plant. The remainder of the figure repreſents aſcending veſſels, and which, as far as I could diſcover, were filled with an oil. Thoſe parts which appear like larger veſſels, and are indicated by *K K K*, were ſhining and tranſparent, and were compoſed of other veſſels, ſo ſmall as to exceed all belief.

Upon cutting this part marked HEG, not far from the end, next H, I was aſtoniſhed to find that this was not, wholly, the young plant, but chiefly its caſe or incloſure, the young plant itſelf, which was contained in it, being not much larger than a grain of ſand. One of the pieces thus cut off I placed before the microſcope, and delivered it to the limner, directing him to make a drawing of the object which preſented itſelf to him, as nearly as it was poſſible for his art to imitate it. This ſlice, which had been cut lengthwiſe, thus depicted, is ſhewn at *fig.* 15, IKLM.

I took great pains to examine many Cocoa-nuts before I could be certain that what in *fig.* 15, is marked IKM, was really that part of the young plant which would penetrate downwards into the earth, and become the root, and that what is deſcribed at KLM was that part which would grow upwards into a tree; but I am now ſatisfied that this is the caſe, and that the parts laſt mentioned are the leaves, which in this young plant are already formed.

I many times endeavoured to ſeparate theſe young plants from the integuments incloſing them, but always in vain; becauſe that part which in *fig.* 15 is denoted by IKM, firmly adhered to thoſe integuments. All I could do therefore, was, to cut the young plants in pieces by a longitudinal ſection; in doing which, however, it often happened, that the object preſented three or four ſhapes to the view, by reaſon that I had ſometimes cut the plant directly through the middle, and ſometimes on one or the other ſide. To ſet this alſo before the reader, I have given two drawings of the pieces ſo cut,

omitting only the integuments or circumjacent parts incloſing them.

The firſt is, of a plant which I had, as I believe, cut exactly through the middle, and it is ſhewn at *fig.* 16, NOPQ. Here, NOQ, is the part which would become the root, and OPQ, that which would grow upwards into a tree. And, in this young plant, are plainly to be ſeen the leaves with which it is naturally furniſhed.

The other, is of a plant which I judged, had not been cut through the middle; for which reaſon it did not appear ſo large as the former, nor were the leaves equally conſpicuous. This is exhibited at *fig.* 17, RSTABZ. The place of the future root in this plant is marked by RSZ, and that of the ſtem by SABZ.

Although I frequently repeated theſe experiments, it was only twice that I could obſerve the upper part or future ſtem of the plant, in drying, ſeparate itſelf from the circumjacent parts. This ſeparation I have cauſed to be expreſſed in the ſame *fig.* 17, at SABZ, and at TY.

I have generally obſerved, that the young plant, in that part which, in *fig.* 13, is noted by EHG, occupied not more than one half of the ſpace there repreſented, and lay near the part marked H. But, at one time, I ſaw the young plant occupy only a third part of the ſpace; whence it follows, that ſuch ſpace or cavity was nine times as large as the plant it contained.

Farther, I twice obſerved the young plant to lie, not preciſely in the middle, but rather on one ſide of the before mentioned cavity, whence I concluded, that it had begun to vegetate while in that part, for I ſaw that the circumjacent parts had in that place begun to ſeparate from each other, ſo that, had the vegetation continued, the plant would have found its way out of the ſhell. This ſeparation of the parts is repreſented in *fig.* 17, at AWB.

Moreover, I thought it right to give ſome repreſentation of thoſe

extended parts which ſurround the upper part of the young plant, or, more properly ſpeaking, the whole of that plant.

Let us ſuppoſe then, that I have cut off a ſmall ſlice of that part which in *fig.* 13 is pictured between G and H, and, that in *fig.* 17, a ſmall part of the circumference of this ſlice, and of the ſkin incloſing it, are deſcribed at V W X. By T, and by V W X Y, that ſubſtance is expreſſed, in which the young plant, or rather the upper part of it, is as it were, incloſed and wrapped up. The parts of this ſubſtance, exhibit the appearance of ſmall veſſels, which lie diſpoſed in ſuch ſtraight lines, that they naturally ſeem deſigned to convey nouriſhment to the plant. But, in the part pictured at H, in *fig.* 13, and where there will be found a kind of ſwelling, theſe veſſels are ſtretched out to ſuch a degree of fineneſs, that none of the parts within them can be diſtinguiſhed without the greateſt attention.

As the kernels of Almonds, Walnuts, Peaches, and Plumbs, which are incloſed in ſhells, are denominated the ſeeds of their reſpective trees, ſo the Cocoa-nut, or fruit of the Cocoa tree, ought to be reckoned among the ſeeds of trees. In the ſeeds, however, of the trees I have firſt mentioned, whoſe ſhells are all formed with a ſeam or joining, thoſe ſhells, when the vegetation proceeds, and the kernel ſwells, open at the ſeam, and the young plant in the kernel, having more ſpace afforded it, can expand in its growth, and ſtrike its root into the earth. But the ſhell of the Cocoa-nut has not any ſeam or joining, being of an equal ſtrength and thickneſs throughout, therefore its vegetation muſt be provided for in a different manner; and this I conclude to be as follows. The moiſture in the Cocoa-nut being incloſed and confined on every ſide, when it begins to be agitated by that inteſtine motion, produced by heat, muſt neceſſarily expand itſelf with great violence, and, by that expanſion, the part which contains in it the young plant, is by degrees, as the

plant increaſes in ſize, driven out of the ſhell through the aperture before noted.

Thoſe, who have lived many years in India, affirm, that there is no tree ſo beneficial, or which produces ſo many conveniences to mankind, as the Cocoa; and that it is converted to upwards of ſixty different uſes by man. The nut not only ſupplies him with food and drink, but from the nut is alſo extracted a liquor not much unlike the ſpirit diſtilled from barley, and from the ſame nut vinegar is made. The tree itſelf furniſhes maſts for ſmaller veſſels, and the capillaments or filaments which ſurround the nut are partly wove into ſail-cloth, and partly twiſted into cables, which are uſed even for large ſhips. If the trunk of the tree be pierced with a ſmall inciſion, there will flow from the wound, every day, a quart of excellent liquor, and this operation may be performed twice in the year; the trees, however, which are thus treated, are deprived of their fertility for that year.

If we compare the ſize of the Cocoa-nut, with the very ſmall plant it contains, we may ſafely ſay, that the nut is above one hundred thouſand times larger than the plant, and we may thence conclude that this nut, and the pleaſant liquor it contains, are deſtined by nature, or which is the ſame, by Providence, for the uſe of man, and to ſupply many of his wants.

ON HOPS.

OF the Hops which grow in the Low Countries, thoſe from Liege are preferred to ours here in Holland, and, I doubt not, with reaſon, becauſe the territory of Liege is one degree and an half more to the ſouthward than Holland, conſequently the Hops will ſooner come to maturity there; beſides, in the lands about Liege the ſoil is deeper than ours. The following are the obſervations I have made upon this plant.

I examined by the microſcope, thoſe leaves of the Hop, which compoſe the pod, or caſe, containing the ſeed; which leaves, being remarkably thin, afforded me a very pleaſant object to behold, the veins or veſſels ſcattering themſelves in all directions about the leaves, and, in ſome places, uniting again. Some of theſe veſſels, I perceived to be filled with a red ſubſtance, others were of a ſpiral figure, reſembling thoſe veins which I have obſerved in the leaves of tea.

Many of theſe leaves, I obſerved to have a ſmall ſeed adhering to them, at that part, where the footſtalk of the leaf had been joined. And, indeed, I think, that theſe ſmall leaves thus bearing the ſeed, are ſo formed, that each ſhall produce one ſeed, but, it is my opinion, that the ſeeds, when the leaves do not grow to perfect maturity, cannot ripen.

Many of the ſeeds I diſſected, and found nothing in them, except the young plant, which was chiefly compoſed of the part that would in time become the root. There were, however, two leaves formed

in the plant, but nothing elſe remarkable, except an immenſe number of ſmall veſſels or veins, diſperſed throughout the beginning root.

All theſe ſeed pods or leaves, chiefly in that part through which they had received their growth and increaſe, were covered with exceeding minute globules, glittering with a beautiful yellow, like gold. As far as my eye was able to judge, theſe globules were in diameter about equal to the thickneſs of an hair of one's beard, but ſome of them not ſo large. I do not conſider them to be the fruit of the Hop, but, ſome matter or ſubſtance, iſſuing from the plant, ſuch, for example, as if it was turgid with a ſuperabundant quantity of juices, or, that the heat of the ſun might ſome days be remarkably intenſe, and that by the very great quantity of juices, or their extraordinary expanſion, they had burſt through the veſſels. Many of them I broke, and I did not think that they were covered with any ſhell or coat, farther than that their external ſurface being hardened in drying, exhibited ſomething of that appearance. They contained only a limpid oil, of a glittering yellow, and alſo other globules, much ſmaller, but more ſolid, and which with the oil, filled up the cavity of thoſe firſt mentioned globules.

This appearance of globules, on the ſurface of the leaves, I think very ſimilar to what I obſerved ſome years ago, at a houſe where I was upon a viſit; the back part of which houſe, was covered with a vine, facing the ſouthern ſun. The young ſhoots of this vine, I obſerved to be, in many places, covered with tranſparent globules, and I judged them to have ariſen from the ſuperabundant juices, which, by the heat of the ſun, had been brought forth in ſuch plenty, that there was not a paſſage for them through the narrow veſſels of the branches, ſo that they might be abſorbed by the grapes. And the warmth on this vine ſeemed to me, to be farther augmented from this circumſtance, that the ground which covered the root, was very curiouſly paved with ſmall different-coloured pebbles, without an

herb or blade of grafs appearing between them. And the juice, thus expelled from the branches, was inſpiſſated or thickened on their ſurfaces into globules.

Upon examining the globules on the Hops by the microſcope, I found, that the part which might be called their coat or ſhell, was not ſmooth, but rough, and in wrinkles, occaſioned, as I concluded, by this, that the juice which iſſued from the plant, and formed itſelf into globules, had, in part evaporated, whereby the outer ſurface or ſkin of thoſe globules, contracted into wrinkles.

Theſe yellow globules, when broken, and put into a clean glaſs, I ſuffered to ſtand in the glaſs for ſome days, and then applied myſelf to examine the oil. I found that great part of this oil, had collected itſelf into thin oblong particles, and, in ſuch numbers, that I could not but ſilently wonder at the ſight. Where this oily ſubſtance lay much diſperſed, there, the oblong particles I have mentioned, did not exceed in length the diameter of a very fine thread of wool, but, where the oil was collected in larger quantities, they were four times that ſize. In ſome places, I obſerved oblong particles, with twelve points, iſſuing, as it were, from a center, with one of their ends terminating in a point, the others, blunt or obtuſe.

Now, we may lay it down for a certain truth, that thoſe pellucid and oblong particles, which I have mentioned to be intermixed with the oil, although, by their minuteneſs, they eſcape our ſight, are really a ſpecies of ſalts, and that the bitterneſs which Hops impart to beer, is produced by thoſe ſalts. And we may alſo be aſſured, that theſe minute ſalts, although they may be a thouſand times leſs than what can be ſeen by the microſcope, do yet, agree in ſhape and figure, with the larger ſalts of the ſame ſpecies compounded of them, in like manner as we obſerve in common ſalt, in nitre, or ſalt petre, and in many other ſalts. The ſame may be obſerved, in that kind of ſugar called ſugar-candy; for, upon this becoming damp, on being

expoſed to a moiſt atmoſphere, when it afterwards dried, I have heard women complain of its having loſt its bright colour. Upon examining into the reaſon of this, I found, that the ſurface had been in part diſſolved by the moiſt air, and when, in drying by the fire, it again became hard, an incredible multitude of ſmall particles, very many of which agreed in ſhape with the larger parts, had collected upon the ſurface, and this collection of minute particles, clouded the brightneſs of the ſugar-candy.

But, to return to the ſalts in Hops; how will thoſe philoſophers get over the difficulty, who obſtinately contend, that bitterneſs is cauſed by a ſort of minute hooks in the ſalts, which by their punctures produce that taſte we call bitterneſs?

I have often laid a ſingle leaf of the Hop, ſuch as I have deſcribed it, upon my tongue, and held it there the ſpace of half a minute; for I was deſirous to try the experiment, whether ſuch a ſingle leaf, which is frequently covered with the yellow globules I have deſcribed, could excite a ſenſe of bitterneſs. And, it is not without wonder, I declare, that ſuch a ſingle leaf, upon being ſtrongly compreſſed between the tongue and the palate, ſpread all over my tongue a very bitter taſte, and indeed, much ſtronger than I expected.

Not content with theſe obſervations, I placed a parcel of theſe oily globules, ſome of them pounded or bruiſed, ſome of them entire, in two ſeparate glaſſes, and, with all the attention I was able, I examined them by the microſcope, but I did not find any particular kind of particles in them.

I then placed the glaſſes in my cabinet, and, that no kind of filth or dirt might become mixed with the oil, I covered them with paper. After twenty-four hours had elapſed, I examined them very attentively, and, in ſome few places, I perceived ſome of thoſe oblong particles I have before mentioned, which were very ſmall and thin, and after twenty-four hours longer time, a much larger portion of ſuch

ſalts was diſcoverable. Theſe obſervations were in the winter, when the weather was not favourable for ſuch enquiries; but, had they been made in a milder ſeaſon of the year, I doubt not, that the ſalts would have been formed more ſpeedily, and in greater plenty.

I think it might be worth while, in the ſummer-time, to examine the flowers and bloſſoms of various trees, particularly thoſe, of which bees appear the fondeſt, by which examination it might perhaps be diſcovered, what kind of ſubſtance, if any, and of what qualities or properties, iſſues from ſuch flowers, and adheres to their ſurfaces.

At one time, in the month of October, I was informed by a Hop Factor, that the Hops in that year, were of an excellent quality, whereupon I procured ſome of the ſeed pods, of that year's growth. Upon examination, I found each of theſe ſeed pods to contain thirty or even forty ſeeds. When I had ſtripped the ſeeds of the ſmall leaves or integuments ſurrounding them, I obſerved, that the young plants within them contained, in proportion to their ſize, abundance of oil. I farther noted, what I have already mentioned, that each young plant had two leaves, and theſe in proportion to the minuteneſs of the plant, were remarkably long. Theſe leaves lay in each ſeed compacted and twined together, much like the ſpiral folds in the ſhell of a ſnail; and, when I laid open the folds, I ſaw within them, ſtill more leaves, but exceſſively minute, and which indeed, I could not diſcover in all the ſeeds. From hence it appears, that the ſeeds of the Hop differ from moſt of the larger ſort of ſeeds, and do not contain in them any ſubſtance to nouriſh the young plant, which plant therefore is more perfectly formed than that in the larger ſeed of the Cheſnut.

As to thoſe beautiful globules which I have before mentioned to have obſerved, thoſe, in this ſpecimen of the Hop, were dried, and rather ſhrivelled. Having broken them, I put them into a glaſs, and breathed on them with my warm breath two or three times, where-

upon the oil diſſolved into a wonderfully fluid ſubſtance. The glaſs I then placed, where no duſt could reach it, and, upon examining it the next day, I ſaw ſuch a multitude of ſalts of different magnitudes diſperſed about the oil, as it would almoſt exceed belief to relate. Moſt of theſe ſalts were pointed at each end, but many of them were ſo minute, that their figure could not be known or judged of, but by reference to the larger ones adjoining to them. In ſome of my obſervations on this oil, I found the ſalts to appear in it, at the expiration of only half an hour after it had been put into the glaſs, and they increaſed in number and ſize every hour, the ſmaller growing larger, and the oily liquor evaporating; and I found that this ſpecimen of the Hop plant, contained twice as many ſalts as were in the former one.

I obſerved one thing which ſeemed ſtrange to me, namely, that many of thoſe oblong ſalts which I had ſaid were pointed at both ends, did not extend in a ſtraight line, but were ſomewhat bent or doubled together; but, whether theſe ſalts ſo bent into a bow-like figure, do, for that reaſon, excite the motion or ſenſation in our tongues, which we denominate bitter, I leave to be examined by others.

On COCHINEAL.

WHEN I firſt applied myſelf to inveſtigate the nature of Cochineal, I concurred in the general opinion which then prevailed, that it was the fruit of ſome tree; and, having at the requeſt of the Honourable Mr. Boyle, further proſecuted the examination, each ſingle piece, or fruit, as I then thought it, appeared to contain one hundred or upwards of what ſeemed to me to be very ſmall ſeeds, ſhaped like eggs, each incloſed in its particular membrane; theſe objects, however, I could not bring into view, until the Cochineal had lain in water for ſome hours, and then, the outer ſkin being taken off, theſe apparent ſeeds, which were very ſoft, preſented themſelves; many of which were incloſed in the membranes I have mentioned, which ſeemed to be their natural coats or coverings, and were twice as large as the ſeeds themſelves: the membranes were filled with a watery ſubſtance, of a lovely red, but the ſeeds were of a dark red or tawny colour. The ſeeds themſelves, upon being diſſected, appeared to conſiſt of nothing but very minute globules of a red colour.

The remainder of the Cochineal, or that part of it which incloſed all theſe ſeeds, was compoſed of very thin membranes, which were alſo of a red colour, except that a very ſmall quantity was to be ſeen, of a certain colourleſs ſubſtance, which, to me, had the appearance of an oil. And to give an idea of the general appearance of the figure of Cochineal, I know not any manner of expreſſing it, better than by compariſon, with a parcel of dried black currants, with their ſkins and ſeeds,

regard being nevertheleſs had to the different ſizes of the currants, and the Cochineal. Laſtly, when I divided the membranes or ſeeds of which Cochineal appeared to conſiſt, into as thin portions or particles as I was able, thoſe thin particles, did not, as I may ſay, exhibit any particular colour.

The preceding obſervations I communicated by letter to Mr. Boyle, from whom I received an anſwer, to the following effect: that he had underſtood from a Governor of Jamaica, that Cochineal was produced from the fruit of the fig-tree, when in a ſtate of decay, at which time, there proceeded from thence, certain maggots or aurelias, which changed into flies; that theſe flies ſettling on the trees were there killed by making fires under the trees, the ſmoke of which cauſed them to fall down; after which, they were ſtripped of their heads, the fore parts of their bodies, and their wings, and the remainder preſerved for uſe, ſo that Cochineal was properly, and in truth, the hinder part, or tail of a fly, and conſequently, that my obſervations were ſo far correct, that the ſubſtances I had ſeen were really eggs, ſuch as are found in the hinder part of the ſilk-worm's moth.

To this I replied, that, in my preceding obſervations, it was impoſſible for me to judge, that Cochineal was an animal ſubſtance, becauſe there was nothing to be ſeen in it, that reſembled an animalcule, and that I had concluded, if it had been an animal, it would have been devoured by thoſe minute animalcules, called mites; and I added, that in conſequence of the information communicated by the Hon. Mr. Boyle, in his letter, I had repeated my obſervations, the reſult of which as I communicated them to him, is as follows.

On this renewed inveſtigation of the ſubject, I was fully convinced, that every ſingle grain of Cochineal, was part of an animalcule, from which, not only the head, the fore part of the body, and the wings, had been broken off, but that alſo the legs, and that part of the body

to which the legs are joined, had been thrown away, ſo that nothing was left, except the animal's hinder part; and I imagined, that the colourleſs ſubſtance I before mentioned, and which is to be obſerved in the chinks or creaſes in every grain, is ſome preparation, applied to the Cochineal, when it is collected for ſale, to defend it from the mites, which otherwiſe would deſtroy or devour it.

Theſe creaſes or rings, in every grain of Cochineal, I imagine are, the articulations or joints, in thoſe kinds of maggots or caterpillars, which afterwards change into a flying inſect: And I did not doubt, that, at the proper ſeaſon, when a ſimilar kind of inſects could be found in this country, I ſhould eſtabliſh that fact, allowing only for the difference in ſhape and colour between them, and thoſe which conſtitute Cochineal.

After this, I examined a large parcel of Cochineal, and in it I found ſeveral of the ſhells or coverings of the wings, which ſhells were of a black colour, with each a red ſpot in the middle. Many inſects are provided with theſe kinds of ſhields, ſhells, or caſes, to defend their wings and the hinder parts of their bodies, which are very ſoft, from injury; and, when they prepare to take their flight, they erect theſe ſhields or caſes upright, and ſpread their wings.

In this parcel of Cochineal, I alſo found among the grains, ſome fragments of aurelias, which I concluded had been formed from the maggots or caterpillars of this ſpecies, and, in one of them was a piece of a maggot, which, in part, ſeemed to have been devoured by mites.

The children in this country, are accuſtomed, in the ſpring time, (when the white nettles, or, as they are commonly called, the blind nettles, are in bloſſom) to go in ſearch of a ſpecies of ſmall flying inſects, called by them lady-birds, which, for the moſt part, are to be found on thoſe nettles. The ſubject now before me, cauſed me to turn my thoughts on theſe inſects (though they are ſmaller than thoſe whoſe bodies conſtitute Cochineal) and I employed ſome chil-

dren, at the proper ſeaſon, to collect ſome of them for me; judging that, when ſtripped of their wings with the caſes, and their heads and feet, the remainder would be found to reſemble Cochineal.

Theſe lady-birds, as they are called, I killed with the ſmoke of ſulphur, and afterwards dried them; and when I had taken off the red ſhells or caſes which cover the hind parts of their bodies, I found under them two red wings, the extremities of which were folded together, becauſe, being longer than the caſes, they cannot otherwiſe be covered by them. I alſo took off their wings, feet, and heads, and then I found, that the cavity which is ſeen on every grain of Cochineal, is on the back or upper ſide of the animalcule, and is cauſed by the drying; that part of the grain which appears with a kind of riſing, is the lower part or belly. As to thoſe grains in Cochineal, which have ſmaller cavities than others, I conclude, that they muſt have been the female inſects, whoſe bodies, being filled with eggs, do not admit of their contracting in ſo great a degree; and though the hind parts of the bodies of thoſe inſects which compoſe Cochineal, do ſomewhat differ from thoſe of the lady-birds, yet, I was now, more than ever, aſſured, that, not only the inſect which produces the Cochineal, but alſo thoſe others I have juſt mentioned, are formed from maggots or caterpillars. For, if we conſider the nature of all thoſe flying animals which are bred from caterpillars, maggots, or, what are called gentles, we ſhall find, that all thoſe annular parts, articulations, or circular creaſes, which are in the caterpillars, maggots, and gentles, are alſo found in the flying inſects bred from them; and in the ſame number. To inſtance in the gentle, from which the common fly is bred; if we examine the fly, and conſider its head to be compoſed of one of the annular parts, or articulations in the gentle, we ſhall find that the breaſt to which are joined the ſix feet, contains three diſtinct articulations, and the hind part of the body five more. In a word, the body of the fly is divided

into nine ſeveral parts, joints, or articulations, and ſo many alſo are found in the gentle. This gives the reaſon, why we muſt not ſuppoſe, that the rings or creaſes which we ſee on the grains of Cochineal, are accidentally produced in the drying, for they were compleatly formed in the maggot, from whence the flying inſect iſſued, the hinder part of whoſe body conſtitutes that ſubſtance named Cochineal; of which, if we examine the grains, we ſhall find them to contain ten articulations; and the fore part of the inſect's body, which includes the head and feet, and the wings with their caſes, being compoſed of four joints or rings, it follows, that the Cochineal inſect is formed of fourteen joints, rings, or articulations.

After I had left the grains of Cochineal in water, for the ſpace of twenty-four hours or upwards, I obſerved, that the cavity, which had been cauſed in them by the drying, was ſwelled and extended to its original ſhape, ſo that the grains appeared exactly to agree, in form and make, with the hinder parts of thoſe inſects, whoſe wings and bodies are covered with ſhells or caſes.

An account of ſome pieces of Amber preſented to the Author; alſo of a ſubſtance reſembling burnt paper, reported to have fallen out of the clouds in Courland.

A Pruſſian Gentleman, by profeſſion a phyſician, on a certain time, earneſtly requeſted me, by letter, to receive a viſit from him, and, with the ſame letter, tranſmitted to me, ſome ſmall pieces of Amber, which, he ſaid, were ſent as a preſent to me, from ſome perſons of note in Pruſſia.

In theſe pieces of Amber were ſeveral ſmall animals, namely, a Fly, a Gnat, a Spider, and an Ant. In the two firſt of theſe creatures, I not only plainly ſaw the wings, but, by the microſcope I could diſcover the feathers and hairs on them, and alſo thoſe protuberances or appearances like coral beads, of which the eyes of thoſe inſects are compoſed; I alſo ſaw the hairs, and nails or claws on all of them, as plainly as if they had been placed before the microſcope, without any intervening medium. In one of theſe pieces of Amber, I ſaw a little piece of ſtraw, in which I could diſtinguiſh the tubes or veſſels of which ſtraw is compoſed.

The manner how theſe animalcules became incloſed in the Amber, and the nature and compoſition of Amber, are equally unknown to me; and I cannot ſubſcribe to the theories or opinions of others, which do not ſeem ſufficiently ſupported, nor am I at preſent particularly called upon, to make any farther enquiry into this matter.

The ſame Gentleman, among other ſubjects of converſation, told me, that in Courland, there had been found in a field, ſomething reſembling burnt paper, being as much as two or three ſheets in quan-

tity, which it was reported had fallen from the clouds; that he had procured a piece of it, which he had examined by the microſcope, but could not form any ſatisfactory judgment reſpecting it. And, finding me deſirous of ſeeing this pretended paper, he afterwards ſent me a piece of it.

I had not had this ſuppoſed paper in my poſſeſſion half an hour, before I obtained, by the help of the microſcope, ſo much inſight into its nature, that I judged it to be a vegetable production, of a ſort which grows in the water; and I concluded, that if the fact was, as reported, that it had fallen from the upper region of the air, it had been carried up thither by what is called a water ſpout; though I am much more inclined to believe, that by ſome heavy ſtorm of rain, or the melting of ſnow, (if the country is mountainous) the ponds or ditches might have overflowed, and carried with their current this vegetable production while green, leaving it on ſome field of graſs or arable land, and there, by the ſun and wind, it might be very much dried, ſo as, in ſome meaſure, to reſemble burnt paper: moreover, I was well aſſured, that I had ſeen this kind of ſubſtance in conſiderable quantities in ponds, ditches, or canals, in this country; my only difficulty was, to diſcover, how it acquired the black or apparently burnt colour before mentioned.

To ſatisfy myſelf in this reſpect, I went to ſome ſtagnating pieces of water in the neighbourhood of this town, where I had ſeen this vegetable, which is an aquatic plant or weed, in great abundance, ſome of it I brought home with me, and ſpreading it open between pieces of thick paper, I laid it before the fire to dry. I then perceived that where many pieces lay heaped one on another, their natural green was changed to a blackiſh caſt; but, where the pieces lay ſingly, they preſerved their green colour.

After this, I examined the before mentioned imaginary paper more accurately, and I ſaw very diſtinctly, that it was exactly of the ſame

make and texture, with the pieces of green plant or weed I had gathered; and, upon examining this laſt, when in the ſame ſtate as I took it out of the water, I ſaw by a common magnifier, what ſeemed to me like very thin threads in it, much finer than hairs; they were round, and their membranes or coats very tranſparent, and they were filled with great numbers of green globules, of different ſizes, the moſt of them about the ſixth part as large as a globule of the human blood. And though this green weed, when I firſt laid it to dry, was in parcels heaped together, to the thickneſs of one's little finger, yet, when dried, it was no thicker than common paper, whence may be gathered, what a vaſt quantity of watery particles are contained in this aquatic plant or weed.

In a word, this ſuppoſed paper from Courland, which is there reported to have fallen from the clouds, and the green weed or leaf, prepared by me in imitation of it, are, in their component parts, ſo exactly alike, that they may be ſaid to be one and the ſame. For, in divers of the filaments or threads of the firſt, I could perceive the membranes compoſing them to be the ſame as in the ſecond, and, in an hundred places, I could perceive theſe filaments to be furniſhed with joints, which were alike formed in each ſpecimen.

Theſe obſervations ſhew, how far conceit and imagination will lead ſome people, and who knows, how many perſons may have pieces of this imaginary paper, treaſured up in their cabinets as great rarities?

Of the herb Periwinkle, wherein the opinion that it does not bear any ſeed, is refuted.

I WAS induced to turn my thoughts to the conſideration of the herb Periwinkle, from an opinion which is entertained, that, though it bears a flower, it does not produce any ſeed. I therefore procured ſome bloſſoms or flowers of this herb, as they grew on the ſtalks, for I was well aſſured, that no flower is produced by any plant, which, when it falls off, is not ſucceeded by ſome kind of ſeed. And, upon examining by the microſcope theſe flowers, and the remains, as I may ſay, of ſome of them, which adhered to the ſtalk, in the places where the flowers had fallen off, I very plainly ſaw, that theſe remains were formed for the particular purpoſe of producing ſeed; for, in ſome of them, I ſaw two or three ſeeds, though very minute.

An acquaintance of mine, a reſpectable perſon, gave me ſome of theſe flowers, which he had gathered from a plant, growing in a place, where the rays of the ſun ſeldom penetrated: and the ſame perſon, paſſing by a houſe, where this plant was placed as an ornament, and obſerving that there were ſome ſeeds on it, he brought me a few of thoſe ſeeds with the ſhells or pods incloſing them. Theſe ſeeds were of a dark colour, oblong, and much larger than I expected to have ſeen, and they were incloſed in a ſtrong and tough ſhell. They were not much ſhorter than coffee berries, though the coffee berries are four times as thick; and laſtly, the ſeeds of

the Periwinkle are diſtinguiſhable by the ſame kind of creaſe or chink, as is to be ſeen in coffee berries.

Six of theſe ſeeds, I ſteeped in water for ſeveral hours, in order that I might be able to cut them, through the hard ſhell or huſk, into very thin ſlices; and, upon placing thoſe ſlices before the microſcope, I ſaw, in every ſeed, the young plant concealed. I ſaw likewiſe, in ſeveral of them, the two leaves with which theſe kind of young plants are generally provided, and theſe ſmall leaves, which, in diſſecting the ſeed, I had cut through, appeared ſomewhat of a flat ſhape: I alſo could diſtinguiſh the veins and veſſels in theſe leaves. Upon repeating the experiment, I cut through that place in the ſeed which partly ſhoots upwards into a ſtalk, and partly penetrates downwards into a root. And here, I could diſcern the veſſels, deſtined to convey the juices upwards or downwards, to thoſe reſpective parts of the plant. In ſome of theſe ſeeds, however, the young plant was not compleatly formed.

After this, I cut the outer huſk or ſhell, and the farinaceous ſubſtance which ſurrounded the young plant, into very ſmall pieces lengthwiſe, in order to take the young plant, whole and entire out of the ſeed. And having ſucceeded therein to my wiſh, I clearly perceived in the plant the two oblong leaves I have mentioned, with their veſſels and veins; and I farther ſaw, that the ſides of the leaves, which lay next each other, were ſomewhat flat, the outer ſides of them rounding. The veſſels on the ſides of the leaves, on account of their opacity, I could not perfectly diſtinguiſh. The young plant, incloſed in the ſeed, I judged to be ſixteen times ſmaller than the ſeed itſelf.

The young plant in the ſeed of this herb, Periwinkle, is remarkably long and ſlender; the plant itſelf does not riſe up into a ſtalk, but creeps along on the ground. And, as in this reſpect, it is ſimilar to moſt plants of the vine ſpecies, which are by nature what is called

creeping, and therefore are uſually trained againſt ſome ſupport; ſo, the young plants, in the ſeeds of the Periwinkle, and in that of the Vine, I mean, what is contained in the grape-ſtone, are of a ſimilar ſhape, though the ſeeds themſelves, are wholly of a different figure: and, as to the circumſtance, that ſeeds are ſeldom found in the Periwinkle, whence the notion of its being entirely deſtitute of ſeeds, ſeems to have proceeded, I gueſs this to be the reaſon, that, it is generally planted in the moſt obſcure and unfavourable places, where it receives very few of the ſun-beams.

Moreover, I examined the mealy ſubſtance which ſurrounds the young plant, and found it to conſiſt, in part, of veſicles, of equal ſizes, but much larger, than the veſicles which are found in the cocoa-nut. When I ſtrongly compreſſed theſe mealy particles, I obſerved many oily parts, of a globular form, and ſo large, that they ſeemed to be compoſed of many receptacles of that oil.

Finally, I placed ſix of the Periwinkle ſeeds in moiſt ſand, which I put into a ſtrong and large glaſs tube; this I carried, for the ſpace of an entire month, in my pocket, where, in the day-time, the natural heat of my body was imparted to them; and, at the expiration of that time, I took out one of the ſeeds, but, I did not perceive any alteration in it. I therefore kept the remaining five ſeeds in the ſand, taking care, that they ſhould always be moiſt. And, at the end of another month, I again examined them, but found their figure unaltered, though the ſeeds were grown ſo ſoft, that, they might be broken with one's nail only. I then took the young plants out of the ſeeds, and I could not obſerve in them any tendency towards decay or diſſolution, nor any advance towards vegetation or increaſe.

*Of the root named * Pareira Brava.*

SEEING, in the Philoſophical Tranſactions of the Royal Society of London, the Root named Pareira Brava, very much extolled, on account of the medicinal virtues it is ſaid to poſſeſs, I was induced to publiſh the obſervations I had made on that root.

A gentleman of ſome conſequence in this country, produced to me a piece of this root, adding, that it was difficult to be met with, and was very highly valued, for that a few grains of the powder; adminiſtered to a ſick perſon, would be found of ſingular benefit.

In order to examine this wood by the microſcope, I obtained from this gentleman a ſmall piece, from which I cut off about the quantity of a grain, and this again, I divided into ſtill ſmaller ſlices, ſome by a longitudinal, and ſome by a tranſverſe ſection. I then, by the help of the microſcope, diſcovered, that the wood contained many very large pores, in ſome places diſpoſed ſingly, in others, two or three placed adjoining to each other. I next, put theſe very thin ſlices into a perfectly clean glaſs, and poured water on them, in order to ſeparate from them, the ſalts they might contain, which I was very deſirous to examine. Then, upon applying the microſcope, I obſerved great numbers of exceſſively minute, glittering particles diſpoſed throughout the water. Theſe particles were of various and peculiar ſhapes, very like thoſe ſalts which I have often

* This is the root of an American convolvulus, (the *ciſſampelos Pareira* of Linnæus) brought to us from Brazil. The reader will find it deſcribed in the New Edinburgh Diſpenſatory, being an improvement of Dr. Lewis's.

found in ſea-fiſh. Then, becauſe I imagined that theſe particles, as far as I could judge by my eye, were no other, than abſolute ſalts, I immerſed ſome of them in burnt wine, to ſee whether they would be diſſolved in the wine. But, all of them preſerved their ſhapes unaltered, ſome of them exhibiting on the glaſs, a triangular figure, and ſome being perfectly ſquare. But, it was my opinion, that theſe ſalts, had been incloſed in certain veſicles in the root, and, when extracted from them by the water, had concreted into the ſalts I have deſcribed; for, I had obſerved the Pareira Brava to be furniſhed with many of thoſe veſicles.

Not having fully ſatisfied myſelf by the examination of this piece of the Pareira Brava, I endeavoured to purchaſe ſome of the root in our town, but I found, that the very name of it was unknown here; however, in a neighbouring town, where it had been in uſe for about a twelvemonth, I procured an ounce and a quarter, and, upon comparing this with the former ſpecimen, by the help of the microſcope, I found them to correſpond exactly.

This laſt-mentioned root, was a piece, ſplit lengthwiſe, and, as near as I could judge, of five years growth: it was half an inch in thickneſs, and the texture of it appeared to me of a wonderful make.* I divided a ſmall piece of it, into very minute fragments, and, putting them into a clean glaſs with ſome rain water, I cauſed the water to boil, until more than half of it was boiled away, the remainder I took off the fire, judging, that the ſaline particles, were, by this boiling fully incorporated with the water. In this water, however, I diſcovered nothing by the microſcope, except ſeveral very ſmall and thin membranes ſwimming on the ſurface: I therefore expoſed ſome drops of it to the air, in order, that the evaporation of the moiſture might cauſe the ſalts to concrete. But, in a ſhort time,

* The author has not given a figure of this root.

there appeared ſuch a membrane or film on the ſurface of the water, that nothing could be diſtinguiſhed in the fluid, except ſome exceſſively minute particles ſwimming in the water in ſuch multitudes, that, if ſome of them had not collected together in the form of ſalts, I could not have diſcovered them. And, I could not ſufficiently admire, that from ſo ſmall a fragment of the root, ſuch a quantity of ſalts had paſſed into the water.

After this water had ſtood undiſturbed for ſome time, and the films on it were ſubſided, I put a drop of it, about the ſize of a pin's head, into a clean glaſs, and mixed with it ſome blood, which, by the puncture of a needle, I drew from my finger. Whereupon I ſaw, that the globules of blood from whence its redneſs proceeds, were, upon being thus diluted, more ſeparated and ſcattered than I remember to have ever obſerved. There was alſo this remarkable appearance, that moſt of the globules had a kind of ſinus or cavity in them, the ſame as if one had a bladder filled with water, and by preſſing a finger on the middle of the bladder, made a cavity or furrow in it. And, when the globules, after aſſuming a flat ſhape (for when they are ſomewhat diſperſed or ſeparated, their extreme ſoftneſs cauſes them to become flat) got ſomewhat cloſer together, they put on an oval figure, and then, the cavities I have mentioned, alſo became ſomewhat oblong. But, when globules of blood are concreted or coagulated, they exhibit the appearance of a ſolid body, the component parts of which, cannot be diſtinguiſhed by the eye, except that, in the coagulated parts, they ſeem rather to differ in ſize.

Now, having ſo often experienced as I have done, how very ſoft are the globules of blood, and how ſpeedily, when ſlightly in contact, and expoſed to the air, they coagulate, I cannot, in any manner, comprehend, how it is, that thoſe globules when in the veins and arteries, where they ſo ſtrongly propel and compreſs one another, do not coagulate. Still leſs can I comprehend, why, when

the ſkin, or the arteries, are compreſſed with the hand, the blood itſelf does not become thicker.

After this, I cut the root into many ſmall pieces, both longitudinally and tranſverſely, in order to inveſtigate, whether thoſe minute ſalts, which I deemed to be in the root, could be there diſcovered. For, I was perſuaded, that there were in the root, ſome kind of veſicles, full of a certain humour or moiſt ſubſtance, and, that upon the evaporation of the moiſture, the ſaline particles which abounded in it, concreted together, as I have mentioned above.

Having now plenty of the root, to purſue my experiments, I found, that more than one-third part of it, conſiſted of veſicles, ariſing at the inner part of the root, and tending towards the exterior. In theſe veſicles, lay certain minute ſalts, collected as it were in cluſters, ſo that frequently, ſix or ſeven appeared together, in a circular poſition: and, where theſe cluſters were longer than broad, I judged that, at leaſt there were twenty ſalts in every cluſter.

Theſe particles, in my opinion, when firſt formed in the root, are larger; but, that in the drying, they become ſo cloſely compacted together, that they each aſſume different ſhapes, ſome being triangular, ſome quadrangular, &c. which I have alſo obſerved, in moſt things when heaped together promiſcuouſly. From hence, at length I gathered, that theſe ſmall particles, were no other than very minute ſalts.

For my farther ſatisfaction herein, I took ſome of theſe very minute ſalts out of the membranes or veſicles containing them, and after wetting them with rain-water, I put them into a very clean glaſs, and placed them over a burning coal, in like manner as I have practiſed in experiments on the globules of meal. I then obſerved, that theſe particles, which, for the preſent, I will call mealy particles, and which, before, were globular, now aſſumed a flat ſhape of a circular figure. So that, theſe particles may, perhaps,

without impropriety, be deemed farinaceous or mealy parts; for, as I have ſaid, their globular form was changed to that of flat and circular, but of different dimenſions. This experiment I often repeated, and always found the event alike.

Having never before, found theſe collections of particles ſurrounded by a membrane in any other wood, but only in certain ſeeds, I was not content with the examination of this root, Pareira Brava, but applied myſelf to the inſpection of other roots, ſuch as that of the China root*, in which, I not only found the ſame kind of ſubſtance, or particles, as in the Pareira Brava, but, the particles were ſo very large, that I could very plainly perceive in them, the ſame kind of chink, furrow, or creaſe, as I have in another place mentioned, to have obſerved in the grains and meal of wheat. And, as to all theſe mealy particles, in both the ſubjects I have mentioned, I could perceive them, when brought to the fire, uniformly alter their figures, from a globular, to a flat and circular ſhape.

Now, ſince it appears, that the particles in the laſt-mentioned root, have in them theſe chinks or creaſes, and, that when wetted and afterwards dried, they change their figures as before related, we may reaſonably conclude, that the very minute particles which abound in the Pareira Brava, have alſo the ſame kind of chink, or furrow, though ſuch furrow is to us inviſible.

Let us now ſuppoſe theſe very minute particles, which I call mealy ones, contained in the root of the Pareira Brava, to be adminiſtered as a medicine, and by the heat and moiſture of the body to be diſſolved: let us farther ſuppoſe that the particles, ſo diſſolved, are, by the continual motion and agitation of the body, in order, that they may perform their office of reſtoring health, comminuted and broken into other particles of inconceivable tenuity

* This root is very minutely deſcribed in Dr. Aſtruc's Treatiſe on the Venereal Diſeaſe.

and fineneſs. We do indeed, hereby gain ſome inſight into the manner of Nature's operation of healing; but, in what particular manner, the particles, ſo attenuated, do act in the accompliſhment of her purpoſe, will, if I miſtake not, for ever remain undiſcoverable by human powers.

Farther, I took a portion of the root, in quantity about five grains apothecary's weight, and placed it on the fire, in order to draw from it the oil and volatile ſpirit it might contain. When this was burnt to a coal; in order to diſcover its fixed ſalts, I poured on it a little rain water, which water becoming very turbid and foul, by reaſon of the burnt matter, I ſtrained it through a filtering-paper, and placed portions of it on ſeveral pieces of clean glaſs, to the end, that the watery parts might evaporate. Nevertheleſs, there ſtill remained ſomething of a viſcous matter, from whence I concluded, that ſome parts of the root had eſcaped the fire: this was all that occurred to me worthy of note in this experiment.

A certain phyſician, in converſation on the ſubject, ſuggeſted to me, that if the coal of the root was burnt to a white aſh, the ſalts would certainly be diſcovered. But, though, in attempting to effect this, the glaſs on which the pieces of root were placed, always melted by the violence of the heat, the pieces of wood were never burnt to aſhes.

Hereupon, I placed ſome pieces of the Pareira Brava root, on a piece of charcoal, ſuch as the goldſmiths uſe, and directed the flame of a large candle againſt it, by the blaſt of a blow-pipe; by which means, the root was almoſt all conſumed to a white aſh: this, I caſt into a ſmall quantity of water in a glaſs, and filtering the water, which was very turbid, I let it fall drop by drop on different glaſſes, made perfectly clean. One of theſe glaſſes I placed on a burning coal, in order to evaporate the moiſture, for, at that time, the atmoſphere was very damp, and rainy. When this drop of wa-

ter was evaporated, ſuch a quantity of ſalts appeared, that I was aſtoniſhed at the ſight; for they lay heaped together, in like manner as, in a wood, the twigs and ſmall branches are ſeen ſpread on the ground. After they had remained thus for a ſmall time, though within an hour, they diſſolved into moiſture: I found the ſame effect to follow breathing on them.

Now, what ſhall we ſay of this moſt extraordinary and intimate union of theſe ſalts with the root? For, it has been obſerved, that though the glaſs melted by the vehemence of the heat applied to it, the ſalts in the pieces of root, which lay on the glaſs, were not expelled; though afterwards, when ſurrounded by a ſtronger heat, they were ſeparated from the wood.

When we find theſe things upon experiment, we cannot but reaſon thus with ourſelves; How wonderful is the make and texture of this root, and how powerfully may the ſalt which is thus cloſely united to it, act as a medicine on the human body! For my part, if I may ſpeak my opinion, it is, that the make of theſe ſalts is not to be altered by the power of fire.

Again, upon conſidering whether the charcoal, which I had uſed in the preceding experiment, might not poſſibly have ſome foulneſs or extraneous matter on it, which was imparted to the root whilſt burning, I placed ſome pieces of the Pareira Brava on a ſilver plate, and, when they ſeemed to be quite burnt to aſhes, and were glowing hot, I threw them into ſome rain water, which had been boiled in a clean veſſel well tinned, and only uſed to boil water for the making of tea or coffee. This water, after ſtraining it through filtering paper, I placed in four ſeparate glaſſes, and ſuffered it to remain there all night. The next day, the atmoſphere being dry and clear, I examined them by four ſeveral microſcopes, and found, that the greateſt part, but not the whole, of the water was evaporated. The event of the experiment was, however, the ſame as in the laſt, namely, that an innumerable multitude of the ſalts before deſcribed, were to be ſeen, and that more diſtinctly than before.

On the formation of the cryſtalline humour of the Eye, in various animals, birds, and fiſhes.

THE cryſtalline or tranſparent body or ſubſtance, (which is commonly called the cryſtalline humour) of the Eye, is, in conſiſtence or hardneſs, almoſt the ſame as a preſerved nutmeg. When I firſt began to make my obſervations on it, I cut off, with a ſharp razor, ſome ſmall pieces or ſlices, and found it to conſiſt of a ſort of ſcaly particles, laid one on another, in a kind of circular form, taking their origin from the center, and all of them then ſeemed to me, to be compoſed of cryſtalline globules. After I had left this cryſtalline ſubſtance, for the ſpace of three days to dry, it became ſo hard, that it flew into pieces before the edge of the knife, after the manner of roſin. Upon again examining its nature and compoſition, I perceived, not only the ſcaly formation, and in the circular direction I have mentioned, but I diſcovered, that each of the ſcales or coats was compoſed of parts, lying in a circular poſition, and in regular order, in reſpect to each other. In other words, the formation of the cryſtalline humour, may be compared to a ſmall globe, or ſphere, made up of thin pieces of paper, laid one on another: this will ſerve to give an idea of the ſcales or coats above mentioned, and, ſuppoſing each paper to be compoſed of particles or lines, placed ſomewhat in the poſition of the meridian lines on a globe, extending from one pole to the other, this may explain the nature of the component parts of thoſe ſcales or coats.

After theſe firſt obſervations, I employed myſelf, more narrowly to examine, the eyes of oxen and cows; for, I thought, that I had

not then, inveſtigated the formation of the cryſtalline humour, ſo accurately as I ought to have done.

I, therefore, firſt ſat about examining that pellicle or thin membrane, wherein the cryſtalline humour is incloſed, and by which it is, as it were, ſeparated from the other humours, compoſing the ſubſtance of the Eye. I was then, well aſſured, that I ſaw this membrane to be compoſed of threads or filaments, though afterwards, notwithſtanding the greateſt attention that I could beſtow, I could not diſtinguiſh ſuch filaments.

In this examination, I ſometimes, but not often, obſerved, that the ſmall fibres compoſing the filamentary ſubſtance of the external coat of the cryſtalline humour, were united to the before mentioned membrane; whence I concluded, that this membrane was eſſential to the cryſtalline humour, in order to ſmooth any inequalities that there might be in the filaments of its external coat, and make its round ſurface perfectly even.

I alſo conſidered with myſelf, whether this membrane might not be formed, for the purpoſe, occaſionally, by its compreſſion, to alter the figure of the cryſtalline humour; that is, to make its rounding ſhape flatter at times, as the purpoſes of viſion might require; and, if ſo, this part of the Eye which has hitherto been called the cryſtalline humour, ought rather to be named, the cryſtalline muſcle of the Eye: and yet, I cannot affirm with certainty, that I have clearly ſeen this membrane to be compoſed of filaments intermixed one among another, though, I am well aſſured that it cannot be formed in any other manner; for, I have always found every kind of thin membrane which I examined, to be of a filamentary or fibrous make. With regard to this, now under conſideration, I perceived, when viewing it ſideways, that it was compoſed of a kind of ſtreaks perfectly tranſparent, which I concluded to be, ſome lymphatic veſſels, deſtined for the nouriſhment of the cryſtalline humour; but

when I followed with my eye, theſe ſtreaks, or lymphatic veſſels, to the part where they joined the cryſtalline humour, they became ſo ſlender, that they vaniſhed from my ſight.

With regard to the before mentioned ſcales or coats, which compoſe the cryſtalline humour, I found them to be ſo exceedingly thin, that, meaſuring them by my eye, I muſt ſay, there were more than two thouſand of them, lying one on another. For, when I had ſtripped the cryſtalline humour of the membrane in which it was incloſed, I found, that its axis or diameter where it was thickeſt, (for it is not a perfect globe, but ſomewhat flattened) was equal to two third parts of an inch; therefore, from the center to the circumferenee, is one third of an inch; and, as I have found by repeated experiments, that ſix hundred hairs of a man's head, are in breadth equal to an inch, two hundred of them conſtitute the third of an inch. Now, I have ſeen, that where ten of the before mentioned ſcales or coats lay cloſe, one on another, they were not, altogether, equal to the diameter of an hair; therefore, if theſe ten be multiplied by two hundred, it follows, as I have before mentioned, that the cryſtalline humour is, in its ſubſtance or thickneſs, compoſed of more than two thouſand ſcales or coats: and laſtly I ſaw, that each of theſe coats or ſcales was formed of filaments or threads, placed in regular order, ſide by ſide, each coat being of the thickneſs of one ſuch filament.

In order to explain to the reader, the nature of this formation of the cryſtalline humour, that is, how it is compoſed of fibres or filaments, I have, in the following figures, repreſented thoſe filaments by lines drawn in a circle, as accurately as I was able; firſt premiſing, that in Plate VIII. *fig.* 1. ABC repreſents the cryſtalline humour, in an ox's eye, of its natural ſize; B, is the place in that part of the tunica cornea, or horny coat of the eye, through which the rays of light paſs. In the following figures, the natural dimenſions are increaſed, in order that the filaments of which the ſcales or coats are compoſed, may be exhibited more diſtinctly.

In Plate VIII, at *fig.* 2, is repreſented the ſurface of the cryſtalline humour, pictured at *fig.* 1, but, which is here to be conſidered, as if that figure did preſent a circular ſhape to the eye. In this figure, are many lines to repreſent the courſe or direction of the ſilaments, but, it muſt not be ſuppoſed to give a true repreſentation of their numbers, the circumference of the cryſtalline humour of an ox's eye, containing more than twelve thouſand of ſuch filaments. For, ten of theſe filaments laid ſide by ſide are, (as before obſerved) not equal to the diameter of an hair; and the whole axis or diameter of the cryſtalline humour being, as before noted, equal to four hundred hair's breadth, it conſiſts of four thouſand filaments in diameter. And, by the common rules of arithmetic, whereby we find the circumference of a circle, of a given diameter, it will be found, that the circumference of the cryſtalline humour in an ox's eye, conſiſts of $12571\frac{3}{7}$ filaments.

Hence we may collect, how exceſſively thin theſe filaments are; and, we ſhall be ſtruck with admiration, in viewing the wonderful manner they take their courſe, not, in a regular circle round the ball of the cryſtalline humour, as I firſt thought, but, by three different circuits, proceeding from the point L, which point, I will call their axis or center. They do not, on the other ſide of the ſphere, approach each other in a center like this at L, but return in a ſhort or ſudden turn or bend, where they are the ſhorteſt, ſo that, the filaments of which each coat is compoſed, have not in reality, any termination or end. To explain this more particularly, the ſhorteſt filaments MK, HN, and OF, which fill the ſpace on the other ſide of the ſphere, conſtitute a kind of axis or center, ſimilar to this at L; ſo that, the filaments MK, having gone their extent, and filled up the ſpace on the other ſide, in like manner as is here ſhewn by the lines ELI, return back, and become the ſhorteſt filaments, HN. Theſe filaments HN, paſſing on the other ſide of the ſphere, again form another axis or center,

and return in the direction O F, and the filaments O F again, on the other ſide of the ſphere, collect round a third center, and thence return in the direction K M; ſo that, the filaments which on this ſide are the ſhorteſt, on the other ſide are the longeſt, and thoſe which there are the ſhorteſt, are here the longeſt.

In order to exhibit more clearly to the view, the nature and diſpoſition of thoſe filaments, conſtituting each ſcale or coat of the cryſtalline humour, I have given a figure of them, as ſeen ſideways, and which, in the plate, is expreſſed by lines; but it muſt be obſerved, that in theſe figures, the cryſtalline humour is repreſented as if it were of a ſpherical form, and, in the deſcription I call it a ſphere, as being more intelligible in the deſcription, though in truth, it is not perfectly globular, as I have before noted.

In Plate VIII. *fig.* 3, R T P S W Q, is deſigned to repreſent one of the coats of the cryſtalline humour, allowing for the difference in ſhape as before noted: P, and Q are axes or centers, one of which, P, in *fg.* 2, was ſhewn at L; the filaments coming from the point P, (which in *fig.* 2 is L) proceed to V, where they are ſhorteſt; from whence they return towards P, where again they are longeſt, and, from P they proceed towards W, where they are again ſhorteſt. In like manner, the filaments at T, take their direction towards Q, and from thence towards X, and from X again towards Q: ſo that, in this figure (allowing it to be conſidered as an hemiſphere) may be ſeen the one half of the courſe or circuit of the filaments. In a word, the filaments L I, in *fig.* 2, are the ſame as in this, are ſhewn at P S; and the filaments between L and M in *fig.* 2, are here ſeen between P and X, and thoſe between L and O, in *fig.* 2, are here, between P and T; ſo that the filaments which in *fig.* 2, are ſeen between F O L I K E, and in *fig.* 3, in R T P S do repreſent the ſelf ſame filaments.

I muſt here farther obſerve, that the filaments, of which the cryſtalline humour, or rather ſubſtance, conſiſts, are thickeſt about R

and S, and, where they approach nearer, at P or Q, they become thinner or ſlenderer. Finally, upon an attentive examination of the cryſtalline humour, we ſhall be convinced, that its tranſparency is not to be exceeded by any glaſs, although it conſiſts of ſo many thouſand filaments, which is moſt wonderful; and the more, if we conſider, how cloſely the filaments muſt be united, that they may admit the rays of light to paſs through them in ſtrait lines; for otherwiſe, the cryſtalline humour would not be pellucid, but would exhibit a white appearance.

In order to explain this formation of the cryſtalline humour ſtill more plainly to ſome curious gentlemen, I took a ſmall tennis ball, and wound it cloſe round about, with ſome very ſmall twine, confining the twine by pins ſtuck in the ball, in the poſition or courſe which the filaments take; I then ſpread over the whole ſome ſtrong glue, and when it was dry, I took out the pins, and then the twine thus wound round the ball, gave a true repreſentation of the courſe of the filaments as before deſcribed.

I have mentioned in the beginning of this Eſſay, that the parts which I now plainly perceive are filaments, I then thought were compoſed of globules, and this, in ſome filaments, did then ſeem to me very apparent; but, not having ſeen the ſame appearance uniformly in all, I now conclude, that the filaments being (as before mentioned) moſt cloſely united, it might happen, that in the ſeparating them, ſome fragments or particles of one, might ſtick to another of them, and theſe I might miſtake for globules.

After this, I took the eyes of ſheep, hogs, dogs, cats, and other animals, and examined their cryſtalline humours, in the ſame manner as I had treated the eyes of oxen; but, neither in the ſcales or coats conſtituting the cryſtalline humours, nor in the diſpoſition of the filaments, of which each coat or ſcale was compoſed, did I perceive the leaſt difference. Moreover, I extracted the cryſtalline humour,

from the eyes of hares and rabbits; theſe alſo, I found to conſiſt of ſcales or coats, incloſed one in another, and each ſcale or coat compoſed of filaments; but, whereas the filaments compoſing the cryſtalline humour in the eyes of the ſeveral animals I have firſt enumerated, do ariſe from three centers, and thence are diſperſed three different ways round the circumference, the filaments in theſe two laſt mentioned animals, take only a twofold courſe or direction. This is ſhewn in *fig.* 4, A B C D, which repreſents the hemiſphere, or one half of the cryſtalline humour, in the eye of an hare or a rabbit. E, is the center near the pupil or ſight of the eye; theſe filaments, compoſing the coats or ſcales, paſſing through, or near the central point E, take their courſe, ſome towards F, and others towards G, ſo that F and G, on the contrary ſide, conſtitute another central point.

I alſo made a drawing, which is copied at *fig.* 5, of the ſame object, as it appeared when viewed ſideways, in order more clearly to ſhew the nature of theſe laſt mentioned filaments, which, with a kind of fibrous ſubſtance, compoſe each ſcale or coat. I will ſuppoſe then, that the filaments, which in *fig.* 4, are repreſented between E F, are the ſame which in *fig.* 5, are pictured at the letters I O; ſo that, the filaments proceeding from the point I, that is, in the former figure at E, here end their courſe at N and L, where they are the ſhorteſt, and thoſe at O, take their courſe through or beſide the point or center N, where they are the longeſt, and then terminate, or rather, with a kind of flexure or bending, return as here repreſented. In a word, thoſe filaments, which, on this ſide, appear neareſt the center, would, on the farther ſide be ſeen remoteſt from it.

In theſe experiments, I always endeavoured, to diſcover the formation of that part of the Eye which anatomiſts call the vitreous or glaſſy humour, and, which in great part, ſurrounds the cryſtalline humour, becauſe I was well aſſured, that this vitreous humour, was

not a watery ſubſtance, but rather a kind of pellucid muſcle; but, notwithſtanding all my endeavours, I could not form any determinate or certain judgment on this head, becauſe the ſubſtance of this vitreous humour, always changed into a kind of watery matter.

Moreover, I examined the eyes of fiſhes; theſe are perfectly ſpherical, and I found, that they conſiſted of the ſame kind of thin coats or ſcales, laid one on another, as I have deſcribed the eyes of animals to be formed; each coat or ſcale, was alſo compoſed of filaments, but, theſe filaments have not that kind of bending courſe, as in animals; and, with all my endeavours, I could not diſcover in what direction they were placed; for, where the filaments draw towards a point or center, they are ſo exceedingly ſlender, and cohere ſo cloſely, that they eſcape the ſight, and cauſe ſuch a confuſion of objects, that I cannot be certain, whether they terminate in that center, or return back again from it. *Fig.* 6, A B C D, repreſents the cryſtalline humour or ſubſtance in the eye of a cod-fiſh; and, though I drew the lines, here made to repreſent the filaments, from the center or point A, to the center or point C, with only a pair of compaſſes, wider apart than in the other figures, yet the filaments which compoſe theſe ſcales or coats, are not in fact thicker, except in the middle at B and D, and the nearer they approach the point A or C the thinner they are. *Fig.* 7, ſhews the natural ſize of the cryſtalline humour in this eye.

I alſo examined the cryſtalline humour in the eyes of birds, only to ſee how the filaments compoſing their coats or ſcales, took their courſe; and, at length, after many obſervations, I found the filaments, in the eye of a turkey, to take the ſame direction, as thoſe in fiſhes: but whereas the cryſtalline humour in the eyes of fiſhes is perfectly round, that in the eyes of birds, is flattened, as at *fig.* 8, lying with its flat ſide D, next the tunica cornea or horny coat of the eye. And, upon my cutting with a ſharp knife many pieces of the ſcales or coats

compoſing it, in order to reduce the ſize ſmaller, it altered its figure to an oblong and flat ſhape, as ſhewn at *fig.* 9, where E is the ſame part which, in *fig.* 8, was ſhewn at D; being the point where the filaments are united, or, in other words, where they ſo cloſely approach, and are ſo exceedingly ſlender, as to become inviſible: hence we may conclude, that the filaments which lie neareſt to the central point, being very thin, do thereby produce the oblong round ſhape, and, where the cryſtalline humour is larger, the filaments in the middle are thicker, and thus cauſe the ſhape to be flattened, which I myſelf have ſeen; for the filaments in the eye of a turkey, where they were thickeſt, were, ſingly, larger than thoſe in the eye of an ox, hog, or ſheep.

I have often, while looking in a mirror, taken notice of that liquid ſubſtance or moiſture, with which the exterior membrane or coat of the eye is covered, and, in which liquid, there are always ſome few very minute globules intermixed; which moiſture, and the globules in it, as often as we ſhut our eye-lids are thereby made to change their places: ſeeing this, I gathered the reaſon, why it is neceſſary for terreſtrial animals to be furniſhed with eye-lids (for fiſhes, and other inhabitants of the waters do not need them) and, that if it were not for the eye-lids, we ſhould become blind; becauſe if the eye-lids did not continually, when we cloſe them, moiſten the external membrane or coat of the eye, its ſurface would grow dry, and contract in wrinkles, eſpecially in ſtrong ſunſhine, or when we approach a large fire. And I think it very probable, that there is continually, ſome kind of humour or moiſture, protruded from the inner part of the eye through the tunica cornea, which, by the eye-lids, is ſpread over the eye: for, in ſeveral eyes of hogs, whoſe bodies had been immerſed in hot water, to facilitate the ſcraping off the hair, I almoſt always ſaw a thin membrane, lying on the outer ſurface of the tunica

cornea, which was ſomewhat ſcalded by the water, and therefore might eaſily be taken off; and, upon compreſſing the ball of the eye between my fingers, I ſaw in many places, a thin watery matter, iſſue from the tunica cornea, and appearing on its ſurface, like vapour or ſteam, adhering to a glaſs, and, when the preſſure was continued, the watery particles, which ſtood on the ſurface, in the form of minute drops, were ſo much enlarged, as to run into one another. And we need not wonder at this appearance, when we conſider, that the tunica cornea is compoſed of nothing but particles, like ſtreaks or fibrous parts with their ramifications, and all of them very thin and ſlender.

I at one time cut the tunica cornea of an ox's eye into ſuch thin ſlices, that the thickneſs of it was ſeven times divided, and, in each of thoſe ſeven parts, I ſaw with great admiration (and more diſtinctly than I had before done) the great multitudes of pellucid ſtreaks or fibres intermixed together, many of which I judged were a kind of blood veſſels, though ſo ſmall and ſlender, that they would not admit the globules of blood, which cauſe its red colour, to paſs through them; and I conclude that, when we rub our eyes, thoſe veſſels may, by the preſſure, be ſo extended, as to admit the red globules of blood, which, for a time, ſtagnating there, cauſe the eyes to appear red, or, what is commonly called blood-ſhot.

But, to return to the eye-lids, it is my opinion, that they never can be conſidered as in a ſtate of reſt, except when they are ſhut; and hence it is, that we cannot keep them ſteadily open, for any length of time, without applying ſome external force: and, as it were, to give them reſt, we frequently (and involuntarily) cloſe them; which involuntary motion in the eye-lids, does, I doubt not, by preſſing on the orifice of ſome minute lymphatic veſſels, cauſe them continually to emit ſmall portions of the lymph, whereby the tunica cornea is continually kept moiſt, as has been before obſerved. And I have ſeen perſons, in a public audience, when very attentive, cloſe their eyes, though ſome did this more frequently than others.

Myſelf, and thoſe of my family, have often, when contemplating objects by the microſcope, ſeen an appearance of ſmall globules before the ſight,* which, I have no doubt, were particles iſſuing from the veſſels in the eye, and lying on its ſurface: theſe, with the leaſt motion of the eye, ſeemed to be in great agitation, and many would affirm, that they ſaw living creatures before their ſight; but whoever gives this ſubject an attentive conſideration, will find, that theſe globules or ſtreaks, though they ſeem, while the eye is kept ſtill, to be in motion, ſometimes upwards and ſometimes downwards, yet they do not alter their poſition in reſpect of each other; and perhaps at another time we ſhall ſee none, or if any, of a very different kind. I believe, however, that this appearance is what has led ſome people to fancy, that they beheld animalcules moving in water, even after it has been boiled, and to affirm, that theſe are the ſame kind of animalcules which I profeſs to have plainly ſeen: but we muſt forgive ſuch perſons their error, conſidering they know no better.

* The Tranſlator can give a ſtrong ſimilar inſtance, from his own painful experience; for, having met with an accident by which the ſurface of his eye was injured, the conſequence was, for ſome hours after the hurt, an appearance of minute, wonderfully bright globules, ſeeming to whirl round the ball of the eye with a rapidity like lightning; and, for ſeveral following days, many dark ſpecks, in motion before the ſight; but all, as Mr. Leeuwenhoek ſays, preſerving the ſame diſtance in reſpect of each other: one of theſe in particular, appeared in ſize, colour, and ſhape, much like a common fly, which ſeemed to be running along the wainſcot of the room, or upon the table.

ADDITION, BY THE TRANSLATOR.

THE preceding Eſſay is one of the moſt curious, and the Tranſlator conceives, that his Readers will deem it the moſt intereſting, of any in this Work; foraſmuch as it reſpects the choiceſt corporeal gift of God to his creatures, the Bleſſing of Sight: and, for the information of thoſe, who are not acquainted with the particular ſtructure of that wonderful Organ, the Eye; the following deſcription of it is ſubjoined, taken from Mr. Adams's Eſſay on Viſion, a ſmall Treatiſe, well worthy the peruſal of every one.

"OF THE GLOBE OF THE EYE.

" If the conſtruction of the Univerſe were not ſo evident a proof of " the exiſtence of a ſupremely wiſe and benevolent Creator, as to " render particular arguments unneceſſary, the ſtructure of the eye " might be offered as one, by no means the leaſt; this inſtance, " among numberleſs others, demonſtrating, that the beſt perform- " ances of art are infinitely ſhort of thoſe which are continually pro- " duced by the DIVINE MECHANIC.

" The globe of the eye, or the organ of ſight, may be defined in " general as a kind of caſe, conſiſting of ſeveral coats, containing " three pellucid humours, which are ſo adjuſted, that the rays pro- " ceeding from luminous objects, and admitted at a hole in the fore " part of the eye, are brought to a focus upon the back part of it, " where they fall upon a ſoft pulpy ſubſtance, from whence the mind " receives it's intelligence of viſible objects.

" It is not to be expected, that any account given of the eye can be " altogether accurate; for as it is impoſſible to examine all the " parts of the eye whilſt in a natural and living ſtate, ſo it is alſo " nearly impoſſible, when it is taken out of its ſocket, to preſerve

" the figure of the parts entire; a circumſtance which accounts for
" the diſagreement we find among anatomiſts.

" *Of the Coats of the Eye.*

" The eye is compoſed externally of three coats, or teguments,
" one covering the other, and forming a ball perfectly globular, ex-
" cept at the fore part, which is a little more protuberant than the
" reſt; within this ball are three different ſubſtances called humours.

" The firſt, or outer coat, is called the *ſclerotica;* the ſecond, or
" middle one, is called the *choroides;* the interior one is named the
" *retina.*

" *Sclerotica. Cornea.*

" The exterior membrane, which incloſes and covers the whole eye,
" is called the ſclerotica and cornea; it is, however, ſtrictly ſpeak-
" ing, but one and the ſame membrane, with different names appro-
" priated to different parts: the hinder and opake part being more
" generally denominated the ſclerotica, the fore and tranſparent part
" the cornea.

" The ſclerotica is hard, elaſtic, of a white colour, reſembling a kind
" of parchment; the hinder part is very thick and opake, but
" it grows gradually thinner as it advances towards the part where
" the white of the eye terminates. The fore part is thinner, and
" tranſparent; it is alſo more protuberant and convex than the reſt
" of the eye, appearing like a ſegment of a ſmall ſphere applied to
" a larger, and is called *cornea*, from its tranſparency. The cornea
" is thick, ſtrong, and inſenſible; its tranſparency is neceſſary for
" the free admiſſion of the light. This membrane is compoſed of ſe-
" veral plates, laid one over the other, repleniſhed with a clear
" water, and pellucid veſſels; theſe plates are more evidently diſ-
" tinct in the fore than the hinder part. The ſclerotica is embraced

" on its outſide by ſix muſcles, by which the eye may be moved in " any direction.

" *Choroides. Uvea. Iris.*

" Under the ſclerotica is a membrane, known by the name of the " choroides ; it is a ſoft and tender coat, compoſed of innumerable veſ- " ſels ; it is concentric to the ſclerotica, and adheres cloſely to it by a " cellular ſubſtance, and many veſſels. This membrane is outwardly " of a brown colour, but inwardly of a more ruſſet brown, almoſt " black. Like the ſclerotica, it is diſtinguiſhed by two different names, " the fore part being called the *uvea*, while the hinder part retains " the name of the choroides.

" The fore part commences at the place where the cornea begins ; " it here attaches itſelf more ſtrongly to the ſclerotica by a cellular " ſubſtance forming a kind of white narrow circular rim : the cho- " roides ſeparates at this place from the ſclerotica, changes its " direction, turning, or rather folding, directly inwards, towards the " axis of the eye, cutting the eye as it were tranſverſely : in the mid- " dle of this part is a round hole, called the pupil, or ſight of the eye : " the pupil is not exactly in the middle of the iris, that is to ſay, the " centers of the pupil and iris do not coincide, the former being a lit- " tle nearer the noſe than the latter.

" This part, when it has changed its direction, is no longer called " the choroides; but the anterior ſurface, which is of different co- " lours, in different ſubjects, is called the *iris* ; the poſterior ſurface " is called the *uvea*, from the black colour with which it is painted. " The iris has a ſmooth velvet-like appearance, and ſeems to conſiſt of " ſmall filaments regularly diſpoſed, and directed towards the center " of the pupil.

" The eye is denominated blue, black, &c. according to the colour " of the iris. The more general colours are the hazel and the blue,

" and very often both theſe colours are found in the ſame eye. It has " been obſerved, that in general, thoſe, whoſe hair and complexion " are light coloured, have the iris blue or grey; and on the contrary, " thoſe whoſe hair and complexion are dark, have the iris of a deep " brown: whether this occaſions any difference in the ſenſe of viſion, " is not diſcoverable. Thoſe eyes which are called black, when nar- " rowly inſpected, are only of a dark hazel colour, appearing black, " becauſe they are contraſted with the white of the eye. The black " and the blue are the moſt beautiful colours, and give moſt fire and " vivacity of expreſſion to the eye. In black eyes there is more " force and impetuoſity; but the blue excel in ſweetneſs and delicacy.

" The pupil of the eye has no determinate ſize, being greater or " ſmaller, according to the quantity of light that falls upon the eye. " When the light is ſtrong, or the viſual object too luminous, we con- " tract the pupil, in order to intercept a part of the light, which " would otherwiſe hurt or dazzle our eyes; but when the light is weak, " we enlarge the pupil, that a greater quantity may enter the eye, " and thus make a ſtronger impreſſion upon it. This aperture dilates " alſo for viewing diſtant objects, and becomes narrower for ſuch as " are near. The contraction of the pupil is a ſtate of violence, " effected by an exertion of the will: the dilatation is a remiſſion of " power, or rather an intermiſſion of volition. The latitude of con- " traction and dilatation of the pupil is very conſiderable; and it is " very admirable, that while the pupil changes its magnitude, it pre- " ſerves its figure.

" Anatomiſts are not agreed, whether the iris be compoſed of two " ſets of fibres, the orbicular and radial, or of either. Haller ſays, " he could never diſcover the orbicular fibres, even with a microſcope; " the radial ſeem viſible to the naked eye, and are ſufficient to an- " ſwer all the purpoſes required in the motion of the iris: when the " pupil is contracted the radial fibres are ſtrait, when it is dilated, " they are drawn into ſerpentine folds.

" In children this aperture is more dilated than in grown perſons; " in elderly people it is ſtill ſmaller than in adults, and has but little " motion; hence it is, that thoſe who begin to want ſpectacles, are " obliged to hold the candle between the eye and the paper they " read, that the ſtrong light of the candle may force their rigid " pupils into ſuch a ſtate of contraction, as will enable them to ſee " diſtinctly. Thoſe who are ſhort-ſighted, have the pupils of their " eyes, in general, very large; whereas in thoſe whoſe eyes are " perfect, or long-ſighted, they are much ſmaller.

" The whole of the choroides is opake, by which means no light " is allowed to enter into the eye, but what paſſes through the pupil. " To render this opacity more perfect, and the chamber of the eye " ſtill darker, the poſterior ſurface of this membrane is covered all " over with a black mucus, called the pigmentum nigrum. This pig- " ment is thinneſt upon the concave ſide of the choroides, near the " retina, and on the fore ſide of the iris; but is thickeſt on the ex- " terior ſide of the choroides, and the inner ſide of the uvea.

" The circular edge of the choroides, at that part where it folds in- " wards to form the uvea, ſeems to be of a different ſubſtance from " the reſt of the membrane, being much harder, more denſe, and " of a white colour; it has been called by ſome writers the ciliary " circle, becauſe the ligamentum ciliare (of which we ſhall ſoon " ſpeak) ariſes from it.

" *Retina.*

" The third and laſt membrane of the eye is called the retina, be- " cauſe it is ſpread like a net over the bottom of the eye; others de- " rive the name from the reſemblance of the net which the gladia- " tors called *retiarii*, employed to entangle their antagoniſts. It is " the thinneſt and leaſt ſolid of the three coats, a fine expanſion of

" the medullary part of the optic nerve. The convex ſide of it " lines the choroides, the concave ſide covers the ſurface of the vi- " treous humour, terminating where the choroides folds inwards. " It is an eſſential organ of viſion; on it the images of objects are " repreſented, and their picture formed. This membrane appears to " be black in infants, not ſo black at the age of twenty, of a greyiſh " colour about the thirtieth year, and in very old age almoſt white. " The retina, however, is always tranſparent and colourleſs: any ap- " parent changes therefore, of its colour; muſt depend upon altera- " tions of the pigmentum which is ſeen through it.

" *Optic Nerve.*

" Behind all the coats is ſituated the optic nerve, which paſſes out of " the ſcull, through a ſmall hole in the bottom of the orbit which " contains the eye. It enters the orbit a little inflected, of a figure " ſomewhat round, but compreſſed, and is inſerted into the globe " of the eye, not in the middle, but a little higher, and nearer to " the noſe; an artery runs through the optic nerve, goes ſtrait " through the vitreous humour, and ſpreads itſelf on the membrane " that covers the back ſide of the cryſtalline.

" Monſ. Mariotte has demonſtrated, that our eyes are inſenſible " at the place where the optic nerve enters: if, therefore, this nerve " had been ſituated in the axis of the eye itſelf, then the mid- " dle part of every object would have been inviſible, and where all " things contribute to make us ſee beſt, we ſhould not have ſeen at " all; but it is wiſely placed by the divine artiſt for this and " other advantageous purpoſes, not in the middle, but, as we have " already obſerved, a little higher and nearer to the noſe.

" *Of the Humours of the Eye.*

" The coats of the eye, which inveſt and ſupport each other, after

" the manner of an onion, or other bulbous root, include its humours,
" by which name are underſtood three ſubſtances, the one a ſolid, the
" other a ſoft body, and the third truly a liquor. Theſe ſubſtances
" are of ſuch forms and tranſparency, as not only to tranſmit rea-
" dily the rays of light, but alſo to give them the poſition beſt
" adapted for the purpoſes of viſion. They are clear like water, and
" do not tinge the object with any particular colour.

" *Aqueous Humour.*

" The moſt fluid of the three humours is called the aqueous one;
" filling the great interſtice between the cornea and the pupil, and
" alſo the ſmall ſpace extending from the uvea to the cryſtalline lens;
" it is thin and clear like water, though ſomewhat more ſpiritous and
" viſcuous; its quantity is ſo conſiderable, that it ſwells out the fore
" part of the eye into a protuberance very favourable to viſion. The
" uvea ſwims in this fluid. It covers the fore part of the cryſtalline;
" that part of this humour which lies before the uvea, communicates
" with that which is behind, by the hole which forms the pupil of
" the eye. It is included in a membrane, ſo tender, that it cannot
" be made viſible, nor preſerved, without the moſt concentrated lixi-
" vial fluid.

" It has not been clearly aſcertained whence this humour is derived;
" but its ſource muſt be plentiful: for if the coat containing it be ſo
" wounded, that all the humour runs out, and the eye be kept cloſed
" for a ſeaſon, the wound will heal, and the fluid be recruited.

" The colour and conſiſtence of this humour alters with age; it
" becomes thicker, cloudy, and leſs tranſparent, as we advance in
" years, which is one reaſon, among others, why many elderly peo-
" ple do not reap all that benefit from ſpectacles which they migh
" naturally expect

" *Cryſtalline.*

" The ſecond humour of the eye is the cryſtalline, which is as " tranſparent as the pureſt cryſtal; and though leſs in quantity than " the aqueous humour, yet it is of equal weight, being of a more " denſe and ſolid nature; in conſiſtency it is ſomewhat like a hard " jelly, growing ſofter from the middle outwards. Its form is that " of a double convex lens, of unequal convexities, the moſt convex " part being received into an equal concavity in the vitreous humour.

" The cryſtalline is contained in a kind of caſe, or capſule, the " fore part of which is very thick and elaſtic, the hinder part is thin- " ner and ſofter. This capſule is ſuſpended in its place by a muſ- " cle called ligamentum ciliare, which, together with the cryſtalline, " divides the globe of the eye into two unequal portions; the firſt " and ſmaller one contains the aqueous humour, the hinder and " larger part the vitreous humour. The cryſtalline has no viſible " communication with its capſule, for as ſoon as this is opened the " humour within ſlips clean out.

" The cryſtalline is placed ſo, that its axis correſponds with that of " the pupil, and conſequently it is not exactly in a vertical plane di- " viding the eye into two equal parts; but ſomewhat nearer the noſe. " It is formed of concentric plates or ſcales, ſucceeding each other, and " theſe ſcales are formed of fibres elegantly figured, and wound up " in a ſtupendous manner; theſe are connected by cellular fibres, " ſo as to form a tender cellular texture. Between theſe ſcales is a " pellucid liquor, which in old age becomes of a yellow colour. The " innermoſt ſcales lie cloſer together, and form at laſt a ſort of nu- " cleus, harder than the reſt of the lens. The cryſtalline has no vi- " ſible communication with its capſule, ſo that when this is opened, " it readily ſlips out: ſome ſay, that a ſmall quantity of water is " effuſed round it. Leeuwenhoek has computed that there are " two thouſand laminæ, or ſcales, in one cryſtalline, and that each

" of theſe is made up of a ſingle fibre, or fine thread, running this " way and that, in ſeveral courſes, and meeting in as many centers, " and yet not interfering with, or croſſing, each other.

" The yellow colour wherewith the cryſtalline is more and more " tinged as we advance in years, muſt make all objects appear more " and more tinged with that colour: nor does our being inſenſible of " any change in the colour of objects, prove to us that their colour " continues the ſame; for in order that we ſhould be ſenſible of this " change, the tincture muſt not only be conſiderable, but it muſt hap- " pen on a ſudden. In the cataract it is opake; the ſeat of this diſ- " order is in the cryſtalline lens.

" *Vitreous Humour.*

" The vitreous is the third humour of the eye; it receives its name " from its appearance, which is like that of melted glaſs. It is nei- " ther ſo hard as the cryſtalline, nor ſo liquid as the aqueous humour; " it fills the greateſt part of the eye, extending from the inſertion of " the optic nerve to the cryſtalline humour. It ſupports the retina, " and keeps it at a proper diſtance for receiving and forming diſ- " tinct images of objects.

" The vitreous humour is contained in a very thin pellucid membrane, " and concave at its fore part, to receive the cryſtalline; at this " place its membrane divides into two, the one covering the cavity " in which the cryſtalline lies, the other paſſing above, and covering " the fore part of the cryſtalline, thus forming a kind of ſheath for " the cryſtalline. The fabric of the vitreous humour is cellular, " the ſubſtance of it being divided by a very fine tranſparent mem- " brane into cellules, or little membraneous compartments, con- " taining a very tranſparent liquor.

" *Ligamentum Ciliare.*

" There is ſtill one part to be deſcribed, which, though very

" delicate and ſmall, is of great importance; it is called the liga-
" mentum ciliare, becauſe it is compoſed of ſmall filaments, or fibres,
" not unlike the cilia, or eyelaſhes; theſe fibres ariſe from the
" inſide of the choroides, all round the circular edge, where it joins
" the uvea; from whence they run upon the fore part of the vitreous
" humour, at that place where it divides to cover the cryſtalline;
" thoſe fibres are at ſome diſtance from one another, but the inter-
" ſtices are filled up with a dark-coloured mucus, giving it the ap-
" pearance of a black membrane.

" *Of the Figure repreſenting the Eye.*

" Figure 10, repreſents a ſection of the eye through the middle,
" by an horizontal plane paſſing through both eyes; the diameter of
" the figure is about twice the diameter of the human eye.

" The outermoſt coat, which is called *ſclerotica*, is repreſented by
" the ſpace between the two exterior circles B F B; the more glo-
" bular part, adjoining to the ſclerotica at the points B B repreſented
" by the ſpace between the two circles at B A B, is the *cornea*.

" The next coat under the ſclerotica is a membrane of leſs firm-
" neſs, repreſented by the two innermoſt circles of B F B, and called
" the *choroides*.

" Adjoining to the choroides, at B B, is a flat membrane, called
" the uvea: a a is the pupil, being a ſmall hole in the uvea, a little
" nearer the noſe than the middle.

" V the *optic nerve*; the fibres of this nerve, after their entrance
" into the eye, ſpread themſelves over the choroides, forming a thin
" membrane, called the retina, and is repreſented in the figure by
" the thick ſhade contiguous to the circle B F B.

" E E is the *cryſtalline* humour; it is ſuſpended by a muſcle B b b B,
" called the *ligamentum ciliare*. This muſcle ariſes behind the uvea
" at B B, where the ſclerotica and cornea join together at b b, it

" enters the capſula, and thence ſpreads over a great part of its " anterior ſurface.

" The *aqueous* humour occupies the ſpace B A Bb Cb.

" The larger ſpace Bb Db BF contains the *vitreous* humour.

" The foregoing deſcription, we preſume, will be found ſufficient " to give the reader a general idea of the conſtruction of this won- " derful organ : for a fuller account we muſt refer him to the writers " on anatomy. Enough has been exhibited to ſhew with what art " and wiſdom the eye has been conſtructed."

The following is a quotation by Mr. Adams, from Reid's Inquiry into the Human Mind :

" If we ſhould ſuppoſe an order of beings endued with every hu- " man faculty but that of ſight, how incredible would it appear to " ſuch beings, accuſtomed only to the ſlow information of touch, that " by the addition of an organ, conſiſting of a ball and ſocket of an " inch diameter, they might be enabled, in an inſtant of time, without " changing their place, to perceive the diſpoſition of a whole army, " the order of a battle, the figure of a magnificent palace, or all " the variety of a beautiful landſcape ? If a man were, by feeling, to " find out the figure of the Peak of Teneriffe, or even of St. Peter's " church at Rome, it would be the work of a life-time.

" It would appear ſtill more incredible to ſuch beings as we have " ſuppoſed, if they were informed of the diſcoveries which may be " made by this little organ, in things far beyond the reach of any " other ſenſe. That, by means of it, we can find our way on the " pathleſs ocean, traverſe the globe of the earth, determine its ſize " and figure, meaſure the planetary orbs, and make diſcoveries in " the ſphere of the fixed ſtars.

" Would it not appear ſtill more aſtoniſhing to theſe beings, if " they ſhould be further informed, that by means of this organ we " can perceive the tempers and diſpoſitions, the affections and paſ-

" ſions, of our fellow-creatures, even when they want moſt to " conceal them? that by this organ we can often perceive what is " ſtrait and crooked, in the mind as well as the body: that it par- " ticipates of every mental emotion, the ſofteſt and moſt tender, as " well as the moſt violent and tumultuous: that it exhibits theſe " emotions with force, and infuſes into the ſoul of the ſpectator the " fire and the agitation of that mind in which they originate? To " many myſterious things muſt a blind man give credit, if he will " believe the relations of thoſe that ſee! his faith muſt exceed that " which the poor ſceptic derides as impoſſible, or condemns as " abſurd.

" It is not, therefore, without reaſon, that the faculty of ſeeing is " looked upon as more noble than the other ſenſes, as having ſome- " thing in it ſuperior to ſenſation, as the ſenſe of the underſtanding, " the language of intelligence. The evidence of reaſon is called " *ſeeing*, not feeling, ſmelling, taſting,; nay, we expreſs the man- " ner of the divine knowledge by *ſeeing*, as that kind of knowledge " which is moſt perfect in ourſelves."

It is too true, that we do not, in general, know the real value of any bleſſing, until we are deprived of it; therefore, let us hear, how the loſs of ſight is pathetically deſcribed by Milton, from his own feeling: In his addreſs to the Light he ſays,

" I feel thy ſovran vital lamp; but thou
" Reviſit'ſt not theſe eyes, that roll in vain
" To find thy piercing ray, and find no dawn;
" So thick a *drop ſerene hath quench'd their orbs
" Or dim ſuffuſion veil'd.——

* This is a literal tranſlation of the Latin words *gutta ſerena*, a diſeaſe, by which the patient is deprived of ſight, though to a ſpectator, the eye does not appear to be injured; becauſe the ſeat of the diſorder is in the optic nerve, and not in the ball of the eye. This was Milton's caſe.

——————" Thus with the year
" Seaſons return, but not to me returns
" Day, or the ſweet approach of ev'n or morn,
" Or ſight of vernal bloom, or ſummer's roſe,
" Or flocks, or herds, or human face divine;
" But cloud inſtead, and ever-during dark
" Surrounds me, from the cheerful ways of men
" Cut off, and for the book of knowledge fair
" Preſented with a univerſal blank
" Of Nature's works to me expung'd and ras'd,
" And wiſdom at one entrance quite ſhut out.

The Tranſlator concludes this ſubject in the words of the ſame great Poet, as conveying a ſentiment, which a wiſe man muſt deem the moſt effectual, if not the only real conſolation under ſuch an affliction.

" So much the rather thou, celeſtial Light,
" Shine inward, and the mind through all her powers
" Irradiate, there plant eyes, all miſt from thence
" Purge and diſperſe, that I may ſee and tell
" Of things inviſible to mortal ſight."

Milton's Paradiſe Loſt, Book III.

On the internal formation of an Ox's Tongue; and on that of the Heart, in Animals, Fowls, and Fiſh.

A CERTAIN profeſſional gentleman of my acquaintance, was urgent with me to examine the formation of a cat's tongue, but this I deferred from time to time, wiſhing rather, to inveſtigate the nature of the human tongue, which I thought would be much more worthy of examination; by reaſon, that it muſt neceſſarily be provided with more muſcles than the tongues of animals: for, this will appear manifeſt, if we conſider how many various motions our tongues muſt exert in ſpeaking, ſinging, or whiſtling.

Not finding an opportunity to procure an human tongue, or that of a cat, I began by examining the tongues of oxen, cutting from them ſmall pieces, both longitudinally and tranſverſely: and, though I thought that a complete deſcription of the whole tongue would take up too much time and labour, I determined to give a drawing of the ſmall muſcles, and point out how they are diſpoſed longitudinally and tranſverſely; for, in an ox's tongue, the number of them is incredible, and in this deſcription will be ſeen, not only the wonderful formation and multitude of theſe minute muſcles, but alſo, we ſhall be fully ſatisfied with regard to the manner in which the tongue is ſometimes extended and ſometimes contracted, both in breadth and thickneſs.

In Plate VIII. *fig.* 11, ABCDEFGHIKLM, repreſents a ſmall piece of an ox's tongue, cut off from the ſide, in that part where the

tongue was thickeſt. In this ſmall piece are to be ſeen various minute muſcles, cut tranſverſely, which are repreſented between BCKL, and DEHI; and among theſe, again, there appear many exceedingly minute particles, alſo cut tranſverſely, which, by reaſon of their ſmallneſs, could by no means be repreſented in the drawing, but each of them may, in fact, be conſidered as a muſcle, for if, by the microſcope, we were to diſſect the before mentioned minute muſcles, we ſhould find them compoſed of ſmaller parts, like a large muſcle, when diſſected and viewed by the naked eye.

Theſe fleſhy muſcles, thus cut tranſverſely, conſtitute the ſubſtance or thickneſs of the tongue; and the muſcles pictured at the three places in this figure, ABLM, CDIK, and EFGH, which are ſhewn lengthwiſe, extend along the tongue from end to end. And, as between the letters BCKL and DEHI, is ſhewn how the fleſhy muſcles appear, when cut tranſverſely, ſo at ABLM, CDIK and EFGH may be ſeen their figure when cut longitudinally.

All theſe fleſhy muſcles, taken together, are not larger, when viewed by the naked eye, than the ſmall piece or particle ſhewn at *fig.* 12.

I alſo judged it right, to take off one of theſe fleſhy muſcles, lengthwiſe, and to cauſe a drawing to be made of it, to exhibit to the eye its true formation, and alſo, as nearly as poſſible, to ſhew thereby, how, in the motion of the tongue, theſe muſcles are exerted, and how they change their figure.

Fig. 3, NOPQ, repreſents this fleſhy muſcle, which I took off lengthwiſe, preſerving the whole of its thickneſs, ſo that none of its conſtituent parts were broken off, except at the extremities NO and PQ: in which muſcle ſeveral bendings are to be ſeen.

Now, ſuppoſing this muſcle, placed lengthwiſe in the tongue, to be contracted in bendings, we muſt conclude, that the tongue then becomes ſhorter and thicker, and the muſcles which lie acroſs it, are

then perfectly ſtraight; and, that when the animal extends its tongue, this fleſhy muſcle, *fig.* 13, NOPQ, and all the others which lie lengthwiſe in the tongue, are extended and become ſtraight, and thoſe muſcles which lie acroſs the tongue are then inflected or bent in like manner as repreſented in the former muſcle at *fig.* 13, NOPQ.

When this muſcle had ſtood three months before the microſcope, it became covered with a ſort of mouldineſs,* which, bearing a reſemblance to ſmall flowers, I directed the limner to imitate them as nearly as poſſible in his drawing, and they are to be ſeen at RRRRRRR.

The fleſhy muſcles, which in *fig.* 11, appear cut tranſverſely, are, in the part lying between BCKL, four diſtinct and ſeparate muſcles, and, in the ſpace between DEHI, ſix of the ſame kind, all of them diſtinct from each other. The parts, or ſpaces between them in the figure, are no other than membranes, and particles of fat, lying within thoſe membranes. For, I never ſaw in ſuch a muſcle as is exhibited in *fig.* 13, NOPQ, any vein, nor any detached particle of fat, but every one of theſe kind of muſcles, as far as I have hitherto obſerved, is always enveloped in a membrane, and, if the ox is a very fat one, particles of fat will be ſeen in the membrane.

It ſhould be remembered, that every one of theſe muſcles muſt have its tendon, or terminate in a membrane which conſtitutes a tendon, and not only ſo, but every oblong fleſhy particle, of which each ſuch muſcle conſiſts, and which appear in *fig.* 13, NOPQ, muſt alſo be provided with a tendon, or terminate in a membrane as before mentioned, and all theſe tendons and membranes (in my judgment) do, together, conſtitute that part which many take only for an inner ſkin, which inner ſkin, or rather muſcular part, covering the tongue all over, is defended, as it were, by a thick external ſkin:

* The ſame appearance is noted by the author, when treating of the young plant in the Coffee-bean.

this latter ſkin is eaſily taken off when a tongue has been boiled, or has lain ſome time in hot water.

This diſpoſition of the muſcles in the tongue is wonderful, and the manner of their acting inconceivable by us, and ſtill more, with regard to the human tongue, when we conſider the variety of ways in which the muſcles muſt move and turn, to produce the effect of ſpeaking, ſinging, and whiſtling, as before obſerved.

The exertions of the fleſhy muſcles in the tongue, are chiefly produced by their aſſuming a ſtraight figure, or by being inflected or bent, contrary to the manner of the fleſhy muſcles in other parts of the body, (as far as has come to my knowledge) for their contraction and extenſion, is produced by means of the multitudes of exceſſively minute wrinkles or crimped up particles, of which each muſcle conſiſts.

After this, I curſorily examined the tongue of an hog, to ſee, whether in it, the fleſhy muſcles were intermixed or laid one acroſs another, in the ſame manner as I have deſcribed in the tongue of an ox: this I firſt inſpected in the thickeſt part of the tongue, on the upper ſide, where it riſes in a ridge like a back; and, I ſaw not only, that the muſcles were diſpoſed in the ſame manner as the ox's, but that ſome few of thoſe which lay the lengthway of the tongue, in ſome places croſſed each other; the tranſverſe muſcles were the ſame as in the ox's. Searching farther inward into the thickeſt part, I there ſaw many fleſhy muſcles lying parallel to each other, lengthways in the tongue; but no others lying athwart or croſſing them. I alſo beſtowed ſome inveſtigation on the thinner parts of this tongue, without finding any thing worthy of note.

I have often employed my thoughts, on the formation of the fleſhy part in the hearts of animals; not particularly to inveſtigate the courſe of the fleſhy muſcles, which I doubt not, has been ſufficiently ex-

amined and explained by others. And, though I determined, if I ſhould obſerve any thing particular in that part of the ſubject, to commit my remarks to writing, yet, my principal object was, to inveſtigate the formation of the very ſmalleſt fleſhy muſcles, and to examine whether any thing might be found therein worthy of note.

For this purpoſe, I took the heart of a ſheep, but, with all my pains, I could not ſucceed in ſeparating or taking off any fleſhy muſcle like that deſcribed at *fig.* 13, NOPQ, for, in the operation, it was ſo torn, and, ſo many of the adjoining parts adhered to it, that I could not then ſatisfy myſelf as to the true formation of ſuch muſcle; nor with regard to the union or connection between it and the adjoining parts.

After this, I tried the heart of an ox, cutting off many pieces, and contriving every poſſible means I could deviſe, to ſeparate a ſmall ſtrip or oblong particle from the adjoining parts, but all to no purpoſe; and, at length, I found, that theſe fleſhy particles were ſo linked together, that it would be impoſſible to ſever them without breaking.

This concatenation, or linking together of the fleſhy parts, (which parts, in treating of the tongue, I have called minute fleſhy muſcles) in the ſubſtance of the heart, is of ſuch a nature, that, at firſt, I deſpaired of being able to repreſent it to the eye by any figure or drawing; but at length, I ſo far ſucceeded, as to exhibit a repreſentation thereof to the reader.

In theſe experiments, I tried the heart of a duck, in order to ſee whether its formation, and particularly this union of the parts, agreed with that of an ox; and I found, that the fleſhy parts in the duck's heart, were linked together in the ſame manner as in that of the ox; and not only ſo, but that I could better give a repreſentation of ſuch concatenation or linking, from the heart of the duck, than from any of the other ſubjects I had examined: and thereupon, I delivered to

the Linner a microſcope, before which was placed an exceeding ſmall piece of the fleſhy part of a duck's heart, directing him to make as accurate a drawing as poſſible, of the object which preſented itſelf to him.

Fig. 14, ABCDEFGHIKLM, repreſents this minute particle magnified, in which may plainly be ſeen, not only how every ſingle fleſhy particle is united or linked to the adjoining one, but alſo, how all the fleſhy particles, ſhewn in this figure, are connected, chained or linked together.

As to the vacant ſpaces appearing in this figure, two of which may be ſeen at BCD, and HNI, we muſt not ſuppoſe, that the fleſhy parts are ſo far aſunder as the drawing repreſents, for I am fully perſuaded, that, when the heart is in its natural ſtate, all the fleſhy particles of which it conſiſts, are ſo cloſe to each other, that nothing but an exceeding thin membrane intervenes, within which membrane the blood-veſſels take their courſe; and there alſo, may ſometimes be ſeen particles of fat, eſpecially where the blood veſſels are larger than ordinary.

Farther, I always obſerved, not only in the hearts of an ox and ſheep, but alſo in that of a duck, all the fleſhy particles, which, when deſcribing them in *fig.* 13, I have called muſcles, but which I cannot here call by that name, becauſe they are not enveloped by membranes peculiar to themſelves; theſe particles, I ſay, which in *fig.* 4, are exhibited at LM or AB, I found, again to conſiſt of great numbers of ſlender oblong particles, which often ſeparated from each other, and at little diſtances united with other particles: but theſe ſmaller particles are not repreſented in the figure, becauſe they had become ſo dried, as not to be viſible to the Engraver.

We may now figure to ourſelves, that the particle of fleſh, which *fig.* 4, exhibits at AB, again conſiſts of an hundred and more oblong particles, and, that a little above AB, they are divided into four

parts, and theſe parts, again united with other fleſhy particles. But how often this ſeparation and reunion of parts take place, and what courſe the particles themſelves take, I have not yet been able to diſcover.

Each of theſe ſeveral fleſhy parts, of which only two are exhibited in *fig.* 4, at BCD, and HNI, were covered with broken and torn fragments of other parts, but theſe I directed the Limner not to delineate, that the concatenation, or the manner in which the particles are linked together, might be better diſtinguiſhed.

After I had cauſed the before mentioned drawing, *fig.* 14, to be made, I again examined various fleſhy particles in the heart of a duck, and, while I was thus employed, I met with one ſmall piece, in which I was convinced, that the concatenation or linking together of the parts, would be ſtill more diſtinctly ſeen. This, being placed before a microſcope of ſomewhat leſs magnifying power, I delivered to the Limner to make a drawing of.

Fig. 15, ABCDEFGH, is this piece of a duck's heart, in which, more plainly than before, can be ſeen the nature of its formation, which will appear ſtill more wonderful, if we conſider, as the truth is, that the connection or linking together of the parts, in the particle which this *fig.* 15, repreſents, was, in the ſubject itſelf, thrice as much as here expreſſed; for, I could not ſeparate a piece of this ſize from the heart, without tearing aſunder twice as many parts or points of union as are here exhibited. This particle was taken from almoſt the outſide of the heart, and, that part which in the figure is marked ABCD, was ſituated pointing towards the ſmall end or tip of it.

In order to ſhew the true dimenſions of the particle repreſented, in this laſt figure, I meaſured it, and found, that the whole length ſhewn in the figure, between the letters EFGH, was, in its natural ſize, not more than two third parts of the breadth or thickneſs of that part

it longitudinally, there appeared ſome difference in the formation, for, whereas the cavity in the hearts of oxen and ſheep, is provided with a tendon; on the contrary, here, inſtead of the tendon, I found various fleſhy parts, with their ramifications, ſpread over the cavity of it. Whereupon, I began to reflect on the great exertion, which birds are obliged to uſe in flying, and how little they are fatigued, even after taking a long flight. But, to ſay any thing ſatisfactorily on this head, many previous obſervations ought to made.

Afterwards, I examined the heart of a cod fiſh, and found its component parts linked together in the ſame manner as I have deſcribed thoſe of the other animals, and of the duck, to be: but when I reflected on the circulation of the blood through this heart, (which appeared more of a fleſhy than a fiſhy nature) and conſidered, how the blood is propelled from it, into a white body, in ſolidity or denſity nearly equal to the heart, whoſe particles are linked together in the manner I have deſcribed, and to how great a degree theſe particles upon the infuſion of the blood muſt be extended, and how contracted in its propulſion, I was more and more loſt in admiration.

On the eye of a Whale, with the Author's obſervations on the preſſure of the ſea-water at great depths.

THE maſter of one of our Greenland ſhips, by name *Iſaac van Krimpen*, upon a certain time, made me a preſent of the eye of a Whale, preſerved in ſpirits of wine. This eye was not of a perfectly ſpherical figure, for its axis, in the thickeſt part, was two inches and ſeven-tenths of an inch in length, and the axis in the thinneſt part was not longer than two inches and an half.

That part of the tunica cornea in front of the eye, which riſes in a globular protuberance, was two inches and an half in diameter.

The cryſtalline humour was not quite of a circular figure, as we generally find it to be in fiſhes; but on one ſide, its ſhape was ſomewhat depreſſed, and the axis thereof meaſured ſeventeen thirtieth parts of an inch, but the axis of that part which was extended towards the object of viſion, was about half an inch in length.

The cavity, wherein the cryſtalline humour is included, was almoſt two inches diameter. The ſubſtance conſtituting the ſurface of, and ſurrounding that cavity, was ſo compact and ſtrong, that I was ſcarcely able to cut it with a very ſharp knife.

Obſerving this, I began to conſider, whether the nature of this fiſh did not require, that the ſubſtance incloſing the cryſtalline humour, ſhould be ſo hard and ſolid; becauſe a Whale ſometimes dives to great depths in the ocean, and, as the fiſh under conſideration, had run out the length of fourteen whale lines, each of which is

an hundred fathoms long; and, in this depth of ſea, the preſſure of water on the bottom, is much greater than is commonly imagined.

For, ſuppoſing the ocean, in any given place, to be 1400 fathoms deep, and each fathom to contain ſix feet, which is the common meaſure, it follows, that the ocean is, in ſuch a place, 8400 feet deep.

It is well known, that a cubic foot of water, ſuch as is found in our canals, weighs 65 pounds, but that the ſame quantity of ſea water, being in its nature heavier, does not weigh leſs than $66\frac{1}{2}$ pounds; but taking it only at 66 pounds, the reſult will be, that every cubic foot of ſea water, where the ocean is 8400 feet deep, does preſs on the bottom with the weight of 554,400 pounds. And, with regard to the whale lines, which I have ſaid are 100 fathoms long, I am told that they are more commonly 120 fathoms, which gives a depth of 16,080 feet.

The ſame Captain Krimpen, in a ſubſequent converſation informed me, that this Whale, having run out the length of fourteen lines, lay on the ſandy bottom of the ſea at that depth, from whence it was weighed up or raiſed by means of the windlaſs, and he added, that he ſhould not have ſucceeded in getting up this fiſh, unleſs the line, which by the harpoon iron was fixed in it, had alſo got a turn or two round the tail, by which means, the Whale was brought up to the ſurface, the tail foremoſt.

The weighing up this Whale, was at firſt ſo difficult and laborious, that ſix men at leaſt, were neceſſarily employed in heaving at the windlaſs, and no leſs than ſix hours were ſpent in the operation. But, when all the lines ſave one, were hove in, the labour became as nothing; for which latter circumſtance, I aſſigned to Krimpen, this twofold reaſon, that the preſſure of the water on the Whale was then greatly diminiſhed; and, that the fiſh abounding with oily or fatty parts, which are lighter than water, would have a tendency to be buoyant.

Let us now ſuppoſe, the eye of this Whale, in that part of it which was expoſed to the ſea water, to contain ſix ſquare inches in its ſuperficies, we may juſtly ſay, that when the fiſh deſcended to the depth of ſea we have mentioned, the preſſure on its eye muſt be equal to 23100 pounds weight. For, ſix ſquare inches are the twenty-fourth part of a ſquare foot, and, if the preſſure on a ſquare foot, at the before mentioned depth, is 554,400 pounds, it follows, that the twenty-fourth part, will ſuſtain a preſſure of 23100 pounds, which is one ton, ſix hundred, and a quarter of a hundred weight.

Seeing then, that ſix ſquare inches of ſpace, at the bottom of the ſea, where it is 8400 feet deep, do endure a preſſure of water equal to 23100 pounds weight, it is no wonder that the ſea in the Bay of Biſcay is not to be fathomed by the lead. For, if the ſea water, at the depth we have mentioned, preſſes on the bottom with the weight we have computed, it follows, that in ſome parts of the ocean, which are at leaſt eight times that depth, the preſſure muſt be eight times as much.

Hence we may fairly infer, that a weight, although of lead, ſuch as that which ſeamen call the deep-ſea lead, cannot, where the depth is ſo very great, touch the bottom, or at leaſt, not in a manner to be perceptible, not only on account of the very great preſſure on the lead, but alſo, on account of the much greater preſſure on the lead-line, by reaſon of its great length, which line itſelf is not much heavier than the ſea water; ſo that the preſſure may very naturally be ſuppoſed to prevent the lead reaching the bottom. Again, it muſt be conſidered, that the ocean, though no current may be viſible on its ſurface, yet is never at reſt; ſo that though the lead, when caſt, ſeems to ſink ſtraight downwards, yet it may be carried away by ſome ſubmarine current, far from the man who heaves it, and the line may be bent and twiſted many ways, by all which means, in ſuch great depths, the lead may be prevented from reaching the bottom. But to return,

The cryſtalline humour in this eye, was ſo cloſely joined to the tunica cornea, as to force it out into a kind of globular extuberance or riſing, which appearance ſeemed very ſtrange to me, having never obſerved the like, in any fiſh or animal.

I took off a piece of the tunica cornea, rather more than an inch in diameter, and, after leaving it a while to dry, I cut it by an oblique inciſion into ſlices, in order to count, with greater facility, the number of thin membranes of which it was compoſed, and I found, that it conſiſted of, at leaſt ſixteen or eighteen of thoſe thin membranes, laid one on another.

This tunica cornea, was lined on its inſide, with a black membrane, every where entirely impervious to the light, excepting an oval aperture immediately in front of the cryſtalline humour, through which the light was tranſmitted; this alſo was to me an unuſual appearance. This oval aperture was in length half an inch, and in breadth ſomewhat leſs than a quarter of an inch.

From this laſt obſervation, a thought occurred to me, whether the whale has not a power of enlarging and contracting this aperture at pleaſure, ſo as to alter the manner of its viſion, as occaſion may require. The ſame power of dilating and contracting the pupil, I remember to have obſerved in the eyes of a cat.

I then employed myſelf, to extract the membrane which covers the back part of the eye, and to examine the optic nerve; this I found to be no larger than the optic nerve in the eye of an ox, but I noted this ſingular circumſtance attending it, that in many places, and I eaſily counted as far as twenty five of them, I ſaw adhering to the membrane, arteries and nerves, which iſſued from the part through which the optic nerve paſſes. Some of theſe, were about the ſize of a common pin, others much larger.

Theſe are the matters, which appeared to me worthy of note on this occaſion, though, if it were poſſible to obtain the eye of a Whale when

newly taken out of the head, I doubt not, that our enquiries might be profecuted much farther, and that, conſequently, greater ſatisfaction might be procured in the inveſtigation.

If we conſider the propagation of the Whale, by compariſon with that of the ſmaller fiſh, we ſhall be led to admire the wiſe diſpoſition of Nature in this reſpect. To inſtance in the common ſhrimp; every one of them may be denominated a female, for they all, without exception, propagate their ſpecies by eggs; and that, in ſuch numbers, that once, when I began to count the eggs on one ſhrimp, I had not got half way through the maſs of them, before I was tired, and gave up the attempt. Such a vaſt number of eggs, produced by one ſmall fiſh is wonderful, eſpecially if we conſider, that every one of theſe minute eggs is nouriſhed by a blood veſſel. Now the larger fiſh, which devour the ſmaller, ſuch as the Whale, the porpoiſe, and the ſword fiſh, are not propagated by eggs, but bring forth their young perfectly formed; for if theſe kind of fiſh increaſed ſo abundantly as the others, the ſmaller fiſh would every one be devoured by them. The Whale in particular, brings forth only a ſingle young one at a time, and is provided with two breaſts filled with milk, and ſuckles the young, after the manner of terreſtrial animals.

I have ſometimes, when reflecting on the enormous bulk of thoſe Whales which were taken at the beginning of the Whale fiſhery, and on thoſe huge bones of Whales, which are in many places fixed up for public view; I have, I ſay, on theſe occaſions, conjectured, that probably thoſe Whales might be of the age of a thouſand years and upwards. For I am perſuaded, that fiſhes never die of old age, foraſmuch as their bones, being always of a ſoft texture, which never grows hard, may always be extended, ſo that the fiſh themſelves are always growing larger. But, terreſtrial animals are expoſed to the changes of the atmoſphere, whereby their bones grow hard, and

when the bones are hardened, the body of the creature cannot be extended to a larger ſize.

Having once, with the aſſiſtance of an able geometrician, and by the eye with the help of quadrants, meaſured the height of the tower of our new church in Delft, we found it to be 299 feet.* So that the depth of the ſea, to which the Whale I have mentioned deſcended, was twenty-ſix times as much as the height of that tower.

* The London reader will be better able to judge of theſe altitudes, (the word *altitude* taken in the ſenſe of the Latin, *altitudo*, from which it is derived, ſignifies both height and depth) by comparing them with the Church of St. Paul's or the Monument: the former of theſe is about 500 feet in height, and the latter 200; ſo that if we call the height of the ſteeple at Delft 300 feet, the Church of St. Paul's is two thirds higher, and the Monument one third lower than that ſteeple. And the depth of ſea from whence the Whale was raiſed, was equal to forty-two times the height of the Monument, and more than ſixteen times the height of St. Paul's.

Of the Quills uſed in writing, and their feathers: on human hair, and the hair and wool of animals.

MY reflections on the nature of thoſe Quills with which we write, as alſo on the general make of the feathers of birds, led me to an inquiry into the manner of their formation; which at length I diſcovered, and found, that Quills are compoſed of ſtreaks, or more properly ſpeaking, veſſels. Theſe veſſels, in every Quill, are threefold. The firſt, or external ones, which conſtitute but a ſmall part of the Quill, are parallel to its length: the ſecond, which are in a much larger quantity, take their courſe round about the Quill, within the former ones: theſe ſecond ſort of veſſels are not ſo cloſely united as to form what may be likened to a ſolid body, but lie one on another like ſcales or coats, in ſuch manner, that the different layers of them may be plainly perceived: the third ſort of veſſels, which compoſe the thickeſt or greateſt part of the Quill, lie lengthwiſe, in like manner as the firſt mentioned ones: this third ſort of veſſels, are alſo diſpoſed in the manner of ſcaly parts laid one on another; and, conſidering the thinneſs of a Quill, and the large cavity it contains, its formation is, in my judgment, the moſt perfect that could be contrived; for, hereby it is made tough and ſtrong, both in its circumference, and in its length. To exhibit the nature of it to the eye, I cauſed a drawing to be made of one.

In Plate IX. *fig.* 1, ABCDEFG, repreſents a common gooſe

Quill, drawn ſmaller than the natural ſize. At A B G, are repreſented thoſe veſſels which compoſe the external part of the Quill, and lie in it longitudinally; B C F G, are thoſe which take their courſe round about it; C D E F, are the veſſels, which, like the firſt mentioned ones, are placed the length way of the Quill.

From theſe obſervations, I diſcovered the reaſon, why ſome Quills when they are ſplit lengthwiſe, in that part where they are hardeſt, form a kind of indented or jagged part in the fiſſure;* namely, becauſe thoſe veſſels, whoſe courſe is round the Quill, are not all broken in an even ſtraight line; eſpecially, as I ſaid before, where the Quill is hardeſt: and where theſe veſſels are heaped together in greater quantities than in other parts. Therefore, to prevent this accident, when the Quill is ſo very hard, it is neceſſary to ſcrape it a little with the pen knife, by which means, in the ſplitting, it will be ſtraight and even.

I have frequently, by the microſcope, contemplated that part of theſe Quills which is called the feather, and alſo the feathers of ſmall birds; and always viewed them with admiration; not only on account of the multitude of parts to be ſeen in them, but alſo, by reaſon of the great numbers, and extreme minuteneſs of the veſſels, of which, not only the whole feather, but every little part of it is compoſed.

To exhibit to the view, the great numbers of veſſels of which the feather conſiſts, I placed a ſmall piece of one before a microſcope, and a drawing of it is given at *fig.* 2, L M N O P Q.

In the preceding *fig.* 1, D H I K E exhibits part of the feather of the common writing Quill, ſmaller, as before obſerved, than the natural ſize. At K, is repreſented a ſmall part of the feather, a piece of which, ſeen by the microſcope, is ſhewn at *fig.* 2, for, if the whole

* This moſt commonly happens in thoſe Quills which have not been, what is called clarified, or when the Quill is ſplit near the feather; this jagged ſhape of the ſplit is well known to ſchool boys, and is denominated by them, cats teeth.

of this piece were to be drawn when magnified, it would appear larger than the whole feather, ſeen by the naked eye. When this ſmall part of the feather is viewed by the microſcope, it will appear, how every one of its parts conſiſts of a great number of ſmaller feather ſhaped parts, all which parts are ſo connected or knit together, as to give ſtrength to the whole feather.

The reader, here, muſt underſtand, that the particle or piece which is ſhewn magnified at *fig.* 2, LMNOPQ, is not, in fact, ſo big as a large grain of ſand: and further, that this particle received nouriſhment in its growth, no otherwiſe than by ſmall veſſels: the reader alſo will advert to *fig.* 3, RS, which is drawn from a microſcope of greater magnifying power, and is ſtripped off from the ſide of *fig.* 2, at MNO, and alſo to *fig.* 4, TV, which is taken from the ſide of *fig.* 2, at QPO.

At LMQ, is repreſented a part, bearing the appearance of globules, of which the interior ſubſtance of this ſmall particle of a feather is compoſed, which agrees with the formation of the correſponding part in the entire feather of the Quill, pictured at *fig.* 1.

In the figures 3 and 4, by R and T, are repreſented ſome ſmall veſſels broken or torn aſunder.

All theſe ſmall particles, each of which may be called a minute feather, not only ſerve to give ſtrength to the whole feather, but are ſo contrived, that in the bird's flight, theſe particles remain ſo cloſely joined together, as to enable it to make a ſtrong impreſſion on the particles of air, by the exact and regular order of the component parts of the feathers. For otherwiſe, birds would not be able to ſupport themſelves in the air. All theſe particles, as I ſaid before, lie in moſt exact order beſide each other, which has induced me frequently to contemplate them, as alſo on account of the innumerable multitudes of veſſels of which the Quill conſiſts.

From this inſtance, in the formation of the feathers of birds, we

doubtleſs, is what has been taken for the marrow of the hair. All this will be better underſtood from the following figures.

Fig. 5, ABCD, is a piece of an hog's briſtle, which I cut by a tranſverſe ſection; EEEE, are the chinks or cracks, ariſing from the drying of the hair as above mentioned, and this hair is burſt or cracked, in the inſide, more than ordinary. *Fig.* 6, FGHI, is a piece of the ſame hair, ſomewhat nearer the ſkin, alſo cut tranſverſely, in which, there are not many cracks, or chinks, but only one, which is, however, ſo large, as to exhibit the appearance of a hole or cavity in the hair, as appears at KLM, and any one, upon ſeeing ſuch an hair as this, would certainly conclude, that the cavity here ſeen, was not accidental, but the natural form and make, and conſequently, that all hairs are hollow. *Fig.* 7, NOPQ, is another piece of an hog's briſtle cut tranſverſely, from which I ſuppoſe the moiſture had evaporated ſo ſlowly, as not to leave the leaſt appearance of a chink or crack: *fig.* 8, is a perfectly black hog's briſtle cut tranſverſely, and, as it exhibited a pretty appearance, I have given a drawing of it. And, though the roughneſs, which is on the edge of the ſharpeſt razor, frequently leaves ſcratches on the face of the hairs thus cut tranſverſely, I almoſt wholly avoided that appearance, for which reaſon, I was better able to point out the ſtreaks or fibres of which the hairs conſiſt.

From the preceding figures, it will appear, how much thoſe are miſtaken, who will have it, that all hairs are round, whereas we ought rather to ſay, that every hair has a figure peculiar to itſelf.

It is my opinion, that the hairs on man's body, do, at certain ſeaſons, fall off, and are again renewed, like the feathers on birds; at leaſt, I have experienced this to be the caſe with myſelf every ſpring, (excepting the hairs on my head and beard) and I have obſerved, that thoſe hairs which ſeemed ready to fall off, could be pulled out with a ſmall pair of pincers, and not cauſe that pain which attends

the plucking out a hair that is firmly fixed; and I have farther obſerved, that thoſe hairs which are pulled out by force, have large thick roots, whereas, the roots of thoſe which are near falling off, are very ſmall and pointed.

Fig. 9, ABCDEFG, and HLMNPQ, are two very ſmall human hairs with their roots; in theſe will be ſeen, that the points or ſmall ends of them, at G and Q, are ſomewhat bent, which I attribute to this, that the points, when thin and tender at their firſt expulſion from the ſkin, had met with ſome obſtacle in their growth, which not being able to penetrate, they were bent obliquely: It is not uſual to ſee hairs bent at the ſmall end, in the manner ſhewn at G, but they moſt commonly appear as at Q.

AB, and HL, are the roots of theſe hairs, which do not appear ſo large, if the hair falls off of itſelf, but, when a hair is pulled out by force, the root appears much larger than the hair itſelf, as is ſhewn in this figure.

The bending of the hairs I have noted above, may very eaſily be occaſioned by their meeting with ſome obſtruction in their growth, and having obſerved a hair on my arm, which was very much bent, I pulled it out, and placed it before a microſcope, in order to ſhew its figure in a drawing.

Fig. 10, ABCDEFGHI, exhibits this hair, in which, ABC is the root, and at AC may be ſeen a ſmall portion of the cuticle or outer ſkin, which adhered to the hair. DEF, indicate a conſiderable bending in the hair, and at GEH is ſhewn a much greater bending, or rather, an entire circular curve.

I have ſaid, that hairs are covered with a coat or bark, in like manner as trees, and that, however ſmall, they are compoſed on the inſide of oblong parts or fibres, and I am perſuaded, that there is no difference between ſheep's wool, which is the ſmalleſt kind of hair, and the hairs of men and animals, except, that ſheep's wool conſiſts

of a leſs number of internal fibres. In order to ſatisfy myſelf in this reſpect, I often broke pieces of wool, and endeavoured to ſplit them into ſmaller parts, wherein at firſt I was unſucceſsful, but at length I found means, not only, diſtinctly to ſee this formation myſelf, but alſo to exhibit the ſame to the view of others.

I therefore delivered to the Limner three microſcopes, directing him, to make drawings of the objects he ſaw.

Fig. 11, KLMN, repreſents a ſmall piece of white ſheep's wool, in which, at L and M may be ſeen, that it conſiſts of a great number of ſmaller hairs, (if we may call the interior parts of the wool by that name;) and who can tell, whether each of the particles, ſhewn at LM, may not again conſiſt of a great number of ſtill ſmaller particles?

This piece of white ſheep's wool, was very tranſparent before it was broken, or cracked; but, at L and M, where many of its oblong component particles are broken or ſevered aſunder, it appeared quite opake, and more of a black colour than tranſparent.

Fig. 12, OPQ, repreſents a piece of white wool, placed before another microſcope; this piece is broken or burſt open only in one place, where alone the internal parts appear, and at Q only two of thoſe internal parts can be ſeen, whereas, in the piece pictured at *fig.* 11, all the internal fibres are divided aſunder.

Obſerving one of the hairs on my arm, to be not only much broken or worn away, by the friction of my ſhirt, but alſo the internal parts to be ſeparated from each other, I pulled out the hair, and placed it before a microſcope: this piece of broken hair, magnified, is repreſented at *fig.* 13, RS, wherein at S, which is the part worn or fretted away, ſome ſmaller particles appear, being the ſmall fibres of which the hair conſiſts.

The preceding experiments and obſervations, will, I truſt, refute the erroneous opinion I have mentioned, that the hairs on our bodies

are hollow within, and, if hair and wool, (which is the hair of ſheep) were not compoſed of many minute hairs or fibres, they would not have that ſtrength and toughneſs which we obſerve in them.

Sometimes, in human hairs, and eſpecially in the very middle of them, I have obſerved a dark line: particularly in ſeveral of the hairs taken from my own beard: and when I attentively examined this dark line, I found it to conſiſt of ſuch minute and ſlender particles, as to be almoſt undiſcoverable even by the microſcope. Examining ſome very ſmall hairs, of three, four or five days growth, and finding ſome to be throughout quite tranſparent, others darkened only in a very ſmall degree, and finally, others with no more than a ſmall dark ſpot on them, I began to conſider, whether this dark ſhade in the hairs, might not proceed from ſome particles of blood in the ſubſtance of the hair, and there dried.

To give the reader an idea of this dark line, I cauſed a drawing to be made of a piece of a ſingle hair, which I concluded to be of three days growth; this is to be ſeen at *fig.* 14, O P Q R S T V W, in which at Q R S and V W O, are the two ends where the piece of hair was cut with a knife: from W to P, or as far as T, the dark line I have mentioned extends, which I have mentioned to be viſible in ſome hairs, and in others not ſo conſpicuous. Laſtly, between R and T P are repreſented thoſe dark ſpots, which are to be obſerved in other hairs.

THE TRANSLATOR, TO THE READER.

IF this tranſlation is a faithful one, I doubt not that the Reader will be led to admire the extenſive range of the Author's reſearches, and the pains he takes to make his diſcoveries intelligible to all; and thoſe who compare his deſcriptions with the productions of Nature at this day, will be equally pleaſed to obſerve their exact coincidence.

But, though I think it may fairly be ſaid, that the works of Mr. Leeuwenhoek are, upon the whole, ſuperior to any that have appeared upon Microſcopical ſubjects, I do not mean to ſay, that there are no inſtances, in which others have not been equally ſucceſsful. A countryman of our own, Dr. Robert Hooke, who was a cotemporary of the Author, and Secretary to the Royal Society ſoon after its firſt inſtitution, publiſhed ſeveral Eſſays, containing his diſcoveries by the Microſcope, with many very judicious and uſeful remarks. In ſome of theſe, Dr. Hooke has handled the ſame ſubjects as our Author, and I ſhall take occaſion, here to introduce a paſſage from that Book, wherein ſome of the particulars reſpecting Feathers, mentioned in the preceding Eſſay, are more minutely deſcribed than by Mr. Leeuwenhoek. *

"Examining ſeveral ſorts of Feathers, I took notice of theſe par-
"ticulars in all ſorts of wing-Feathers, eſpecially in thoſe which
"ſerved for the beating of the air in the action of flying.

"That the outward ſurface of the Quill and ſtem was of a very
"hard, ſtiff, and horny ſubſtance, which is obvious enough, and
"that the part above the quill was filled with a very white and light
"pith, and, with the microſcope, I found this pith to be nothing
"elſe but a kind of natural *congeries* of ſmall bubbles, the films of

* Hooke's Micrographia, p. 165, Edit. 1667.

" which ſeem to be of the ſame ſubſtance with that of the quill, that " is, a ſtiff tranſparent horny ſubſtance.

" As for the make and contexture of the down itſelf, it is indeed " very rare and admirable, and ſuch as I can hardly believe, that " the like is to be diſcovered in any other body in the world; for " there is hardly a large Feather in the wing of a bird, but contains " near a million of diſtinct parts, and every one of them ſhaped in " a moſt regular and admirable form, adapted to a particular deſign: " for, examining a middle ſized gooſe quill, I eaſily enough found " with my naked eye, that the main ſtem of it contained about 300 " longer and more downy branchings upon one ſide, and as many on " the other of more ſtiff but ſomewhat ſhorter branchings. Many " of theſe long and downy branchings, examined with an or- " dinary microſcope, I found divers of them to contain near 1200 " ſmall leaves, (as I may call them) ſuch as EF in the figure* " and as many ſtalks: on the other ſide, ſuch as IK in the ſame " figure, each of the leaves or branchings, EF, ſeemed to be di- " vided into about ſixteen or eighteen ſmall joints, as may be ſeen " plainly enough in the figure, out of moſt of which there ſeemed " to grow ſmall long fibres, ſuch as are expreſſed in the figure, each " of them very proportionably ſhaped according to its poſition, or " placed on the ſtalk E F; thoſe on the under ſide of it, namely, " 1, 2, 3, 4, 5, 6, 7, 8, 9, &c. being much longer than thoſe directly op- " poſite to them on the upper; and divers of them, ſuch as 2, 3, 4, 5, " 6, 7, 8, 9, &c. were terminated with ſmall crooks, much reſem- " bling thoſe ſmall crooks, which are viſible enough to the naked " eye, in the ſeed-buttons of burdocks. The ſtalks likewiſe, I K, on " the other ſide, ſeemed divided into near as many ſmall knotted " joints, but without any appearance of ſtrings or crooks, each of " them about the middle K, ſeemed divided into two parts by a kind

* Plate IX. *fig.* 15.

" of fork, one ſide of which, namely, K L, was extended near the " length of K I, the other, M, was very ſhort.

" The tranſverſe ſections of the ſtems of theſe branchings, mani- " feſted the ſhape or figure of it to be much like I N O E, which con- " ſiſted of a horny ſkin or covering, and a white ſeemingly frothy " pith, much like the make of the main ſtem of a Feather.

" The ſtems of the downy branches I N O E, being ranged in the " order viſible enough to the naked eye, at the diſtance of I F, or " ſomewhat more, the collateral ſtalks and leaves (if I may ſo call " thoſe bodies I newly deſcribed) are ſo ranged, that the leaves or " hairy ſtalks of the one ſide lie at top, or are incumbent on the " ſtalks of the other, and croſs each other, much after the " manner expreſſed in the figure, * by which means every one of " thoſe little hooked fibres of the leaved ſtalk gets between the " naked ſtalks, and the ſtalks being full of knots, and a pretty " way disjoined, ſo that the fibres can eaſily get between them, " the two parts are ſo cloſely and admirably woven together, " that it is able to impede, for the greateſt part, the tranſcurſion of " the air; and though they are ſo exceedingly ſmall, as that the " thickneſs of one of theſe ſtalks amounts not to a 500th part of an " inch, yet do they compoſe ſo ſtrong a texture, as, notwithſtanding " the exceeding quick and violent beating of them againſt the air, by " the ſtrength of the bird's wing, they firmly hold together. And it " argues an admirable providence of Nature in the contrivance and " fabrick of them; for their texture is ſuch, that though by any ex- " ternal injury the parts of them are violently disjoined, ſo as that " the leaves and ſtalks touch not one another, and conſequently ſe- " veral of theſe rents would impede the bird's flying; yet, for the " moſt part, of themſelves they readily re-join and re-contex them-

* Plate IX. *fig.* 16.

" ſelves, and are eaſily by the birds ſtroking the Feather, or draw-
" ing it through its bill, all of them ſettled and woven into their for-
" mer and natural poſture; for there are ſuch an infinite company of
" theſe ſmall fibres in the under ſide of the leaves, and moſt of them
" have ſuch little crooks at their ends, that they readily catch and hold
" the ſtalks they touch."

Here we ſee a perfect agreement between theſe two valuable writers, in deſcribing the ſame ſubject, with this difference only, that the Engliſh author has more minutely deſcribed that curious part in Feathers, which Mr. Leeuwenhoek only mentioned ſlightly; I mean the contrivance of Nature, whereby the ſeveral minute Feathers compoſing the larger, are knit together ſo firmly as to bear the ſtrong exertion of the bird in flying, without yielding a paſſage to the air.

The ſame Author, in treating of hair, has theſe words, " The
" root of the hair was pretty ſmooth, tapering inwards, almoſt like
" a parſnip, nor could I find that it had any filaments, or any other
" veſſels, ſuch as the fibres of plants.

" The top when ſplit (which is common in long hair) appeared
" like the end of a ſtick, beaten till it be all flittered, there being,
" not only two ſplinters, but ſometimes half a ſcore and more.

" For the briſtles of a hog, I found them to be, firſt, a hard
" tranſparent horny ſubſtance, without the leaſt appearance of pores
" or holes in it, and this I tried with the greateſt care I was able,
" cutting many of them with a very ſharp razor, ſo that they ap-
" peared, even in the glaſs, to have a pretty ſmooth ſurface, but
" ſomewhat waved by the ſawing to and fro of the razor, as is viſi-
" ble in the end of the priſmatical body A in the figure.* The ſhape
" of the briſtles was very various, neither perfectly round, nor ſharp
" edged, but priſmatical, with divers ſides, and round angles as
" appears in the ſame figure. †

* Micrographia, p. 157. † Plate IX. *fig.* 17.

An extraordinary quantity of Fiſh on the ſea coaſt near Delft, noted by the Author, with the reaſons aſſigned by him for the ſame.

IN the months of April and May 1716, there were brought to our town of Delft, from the ſea coaſts at Schevling, Catwick, and Terheid, a great quantity of the fiſh called haddocks, which, though very freſh and good, were ſold at a low price. The glut of this fiſh was ſo great, that though in general they are caught with hooks, they were on this occaſion, taken in nets.

Seeing this, I conſidered, that there muſt be ſome particular reaſon, why theſe fiſh ſhould at that time reſort to our coaſts in ſuch multitudes, and I was afterwards confirmed in that opinion, for in a month or two afterwards, not one of thoſe fiſh was to be taken: and the reaſon which I aſſigned to myſelf for the abundance I have mentioned was, that at that time, there was a greater quantity of food for them on the coaſt than uſual, whereby they had been tempted thither.

In order to inveſtigate this matter, I opened the ſtomachs of many haddocks, and found them to be filled with a certain ſmall ſpecies of ſhrimps, called by our fiſhermen meutjens, which are taken among the common ſhrimps, and are uſed for food by people living along the ſhore.

About a fortnight afterwards, on examining the ſtomachs of the haddocks, I found ſome of them quite empty, and others not more

than half filled with the before mentioned ſmall fiſh ; and ſo much was the glut then diminiſhed, that few or no haddocks were taken. Upon enquiring the reaſon of this dimimution from a fiſherman, he anſwered only, that every ſort of fiſh had its ſeaſon, though I ſhould rather have ſaid, in the words of ſcripture, "that where the food is, there will the eagles be gathered together."

At the time there was this glut of haddocks, there was a great quantity of cod fiſh caught on our coaſt, the reaſon of which I took to be, that theſe cod flocked to our ſhores in purſuit of the haddocks which are their food.

About the beginning of October, in the ſame year, there were taken on our coaſts, great quantities of the common ſhrimps, and thoſe in better condition than they are generally found in the ſummer time. Hence I concluded, that the haddocks would again reſort to our coaſts, and that the ſhrimps, to avoid them, would crowd in greater quantities to the ſhores and ſhallows.

To ſatisfy myſelf in this reſpect, and that I might learn what particular kind of food is uſed by the haddock, I cauſed the entrails of a very large one to be brought to my houſe; but, to my great ſurprize, I found not only the ſtomach, but the inteſtines adjoining it, to be entirely empty of food.

I enquired of a fiſhwoman what might be the reaſon of this, who gave me the following anſwer: Our fiſhermen (for ſhe lived at Delftshaven) have a pond or ciſtern, lined at the bottom and on the ſides with timber full of holes, ſo that the water freely paſſes in and out with the tide ; and the fiſh being kept in this ciſtern, can at all times be brought to market alive and vigorous. But the fiſhermen ſay, that when the haddocks are thrown into this ciſtern, they immediately empty their ſtomachs of all the food they have ſwallowed.

Hereupon, I examined a little of the matter or ſubſtance contained

in the inteſtines at a conſiderable diſtance from the ſtomach, and I found the ſame to conſiſt of fragments of ſhrimps mixed with many particles of ſand, rather larger than the ſand found on the ſea ſhore, and which particles of ſand I concluded the haddock had picked up with the ſhrimps from the bottom of the ſea, and had ſwallowed down both together. Among theſe grains of ſand, I ſaw many ſhining particles, ſome thouſands of which, laid together in an heap, would not equal a large grain of ſand: theſe were all of different ſhapes, but, in every one of them, the ſides, angles and points, were ſo ſmooth and glittering, as to be very little inferior in beauty to the moſt poliſhed diamonds. At firſt, I ſuppoſed them to be no other than common ſalt, but I found them to be much more hard and ſolid than our ſalt. After I had ſteeped them a ſhort time in rain water, I could ſtill diſtinguiſh ſome of them, though much diminiſhed in brightneſs; others of them, ſeemed to be partly diſſolved, and to be ſurrounded with ſmaller particles: theſe latter, I concluded to be, ſtill more minute ſalts, which, in diſſolving, had ſeparated from the larger ones, and afterwards concreted in cluſters.

In the month of November in the ſame year, there was another great draught of haddocks on our coaſt, whereupon I went to the fiſh market to examine the inteſtines, when newly taken out of the fiſh: I found moſt of the ſtomachs to be empty of food, but ſome remains thereof in the inteſtines; and, as at the ſame time, great plenty of cod fiſh were caught, I judged that the haddocks, avoiding the purſuit of the cod, and theſe purſuing the haddocks, was the reaſon, that both were taken in ſuch abundance.

Thoſe perſons, who are very nice in their taſte, prefer the haddocks brought to us from Maeſlandſluys, to thoſe that are brought ſtraight from the ſea ſhore, though both are taken near the ſame tract in the ocean. Upon conſidering with myſelf, what might be the reaſon of this difference, I could not aſſign any more probable

one than this, that thoſe haddocks which are brought ſtraight from the ſea ſide, are, as ſoon as taken, thrown into baſkets, to the number of eight or ten in each baſket, and die, thus heaped together, before they are expoſed to ſale: whereas, the fiſhermen at Maeſlandſluys, keep their fiſh for a time in thoſe ciſterns I have deſcribed; and the fiſhermen of Delftſhaven, have alſo a kind of fiſh trunk or well in their boats for the like purpoſe. Therefore, the fiſh which are thus kept alive without food for two or three days after they are caught, are of a much better taſte.

The ſame is experienced in river fiſh, eſpecially trout, which, when caught in the ſummer time, are unpleaſant to the palate, taſting of the herbs on which they feed, but, if kept a few days in ſtew ponds, ciſterns, or other fit receptacles, are much improved in flavour.

But to return to the ſubject of the fiſh market, I obſerved a large cod fiſh, very much diſtended with a quantity of food, namely, haddocks, which it had devoured, when ſome of the ſmaller cod lying near it, appeared empty. Hereupon, I enquired of an old fiſherman, whether thoſe cod fiſh, which were ſo diſtended, did not differ in taſte from thoſe, whoſe ſtomachs were empty; to which he anſwered, that thoſe cod were to be preferred, whoſe bellies were compact or cloſe. This is a phraſe among fiſhermen, applied to thoſe fiſh whoſe roes are not very large, and whoſe ſtomachs are very little, or not at all diſtended with food.

Of the Nutmeg; the young plant in it diſcovered; the root of the Nutmeg-tree examined and deſcribed; with ſome hints from the Author reſpecting the beſt method of preſerving Nutmegs from being injured by inſects.

HAVING, at many different times, employed myſelf in the examination of Nutmegs, in order, if poſſible, to diſcover the young plant of the future tree (which, I was well aſſured they contained) but always without ſucceſs, I at length received, from one of the Directors of the Eaſt India Company, reſiding in our town, a few Nutmegs, and alſo a parcel of powder or duſty matter, which had been found adhering to ſome of the nuts *, to the intent, that I might examine them, and ſee whether this powder had not been gnawed or bitten off the nuts by mites.

With the greateſt accuracy I was able, I examined this duſty matter, and, with all my attention, I could not diſcover in it any mite either alive or dead, but in ſome of the Nutmegs which had been in part eaten away, I found ſeveral ſmall maggots of different kinds, and alſo a few flying inſects which I concluded had been bred from maggots of the ſame ſpecies; but the bodies of all theſe creatures were ſo much ſhrivelled, that I concluded they had been long dead, and that, not being natives of theſe regions, they could not endure the cold of our climate.

* This valuable fruit or ſpice, which, in Engliſh, is called by the ſingle word Nutmeg, is in Dutch denominated Noot Muſcaat, herein agreeing with the botanical Latin name Nux moſchata, the Muſk-nut; it is alſo denominated Nux myriſtica, the odoriferous or ſweet-ſmelling nut.

I next went to our Eaſt India Company's warehouſe, at the time the officers employed to ſort the ſpices were buſy in allotting the Nutmegs according to their qualities, and I brought home with me, two or three handfuls of the refuſe thrown away: any one upon viewing this with the naked eye, would eaſily be led to conclude, that it contained mites, but with my utmoſt attention, I could not diſcover any mites, much leſs their eggs, and only a few of the dead inſects I have before mentioned. I alſo brought home ten or twelve of the moſt damaged Nutmegs, which felt very light in the hand, and were much ſhrivelled: upon examining theſe carefully, I found that moſt part of the duſt or powder, which upon a curſory view might be taken for mites, was nothing elſe than the duſt of the Nutmegs, and the excrements of maggots which had almoſt entirely ſcooped out the inſides of thoſe nuts.

In the examination of theſe and other Nutmegs, it appeared to me, that thoſe which had been gathered unripe, were the moſt liable to be devoured by maggots, becauſe the oily matter in this nut, which pervades its ſubſtance in ſtreaks like the veins of marble, and covers the outward bark in like manner, is contrary to the nature of theſe maggots; for when I cut open the nuts wherein they were, I found the oily part every where uninjured, and on the contrary, all the whitiſh part of the nut conſumed, ſo that thoſe oily parts lay within the nut, exhibiting to me, as it were, a labyrinth of turnings and windings, whereas, the unripe nuts, where the oily ſubſtance was not completely formed, were in the inſides, quite conſumed; I alſo perceived the external coat of the ripe nuts in ſome places bored or eaten through, but in my opinion, when the maggots reached the parts were the oil was fully ripened, they deſiſted from farther biting, and only devoured that part where the young plant is ſituated, and which is the thickeſt part of the nut.

I was much ſurpriſed, that I could not diſcover any mites among

the Nutmegs, becauſe there is rarely any ſubſtance that can be uſed for food, where they are not to be found.

I determined therefore, to examine whether mites fed upon the Nutmeg, and therefore I placed about a quarter of a nut, among a parcel of mites, when I perceived that they fled from it.

Moreover, I took a glaſs tube, ſomewhat larger than a ſwan's quill, one end of which I ſtopped with a cork, and, after putting into the glaſs ſome hundreds of mites, I cut a ſmall piece of Nutmeg of a ſize that I could put it into the tube; and I perceived that the mites next the Nutmeg ſoon died. I then put another piece at the other extremity of the tube where there were many live mites, which alſo in a very ſhort time died.

To ſatisfy myſelf ſtill farther, I took a glaſs tube, thirteen inches long, and half an inch diameter; one end of this I cloſed by melting it, and put as many mites into it as I computed in bulk altogether to be equal to half a cubic inch, and, according to the exacteſt computation I could make, they were in number 150,000.

After theſe mites had been about a quarter of an hour in the tube, they ſpread themſelves from the maſs in which they were, when firſt put in, and diſperſed all over the glaſs; I then ſplit a very ſouud and good Nutmeg into four parts, one of which parts I placed in the open end of the glaſs, ſo that I might obſerve by the microſcope, what effect it would have on the mites when they approached it.

Moſt of them I ſaw creeping towards the open end of the tube, and when they came to within about a ſtraw's breadth of that part where the piece of nut touched the glaſs by two of its points, many of them returned back, though they might have paſſed by the nut without approaching nearer than the eighth part of an inch to the main ſubſtance of it.

The retreat (ſo to expreſs myſelf) of theſe multitudes of mites, afforded me a very pleaſant ſpectacle, for here it appeared, that the exhalation or vapour proceeding from the piece of Nutmeg, was ſo

rently had belonged to maggots of the ſame ſpecies, whence I concluded, that during their growth, theſe maggots change their ſkins in like manner as ſilk worms are obſerved to do.

I alſo found in theſe nuts, two flying inſects of different kinds, but they, as well as the maggots, notwithſtanding all the care I could take, ſoon died, whence I was more convinced that the maggots which feed on the Nutmeg are not natives of theſe regions, and I do not doubt, that if the warehouſes in India, where Nutmegs are kept, were to be well fumigated with ſulphur, once a month, (for if this is done only once, thoſe inſects which are at that time alive may be killed, but the minute maggots incloſed in the eggs will eſcape unhurt, and therefore the fumigation muſt be repeated) by this operation the Nutmegs would, in a great meaſure, be preſerved from damage. And I alſo think, that it would be very proper to fumigate the holds of the ſhips with ſulphur, by which means theſe maggots, and thoſe whoſe nature it is to perforate and feed on timber; alſo, the inſects called cock roaches, the millepedes, or thouſand legs, and even mice, which hide themſelves in the holds of ſhips, muſt be all deſtroyed.

I endeavoured, three ſeveral times, to cauſe the Nutmeg to vegetate, but I had not the good fortune to ſucceed; which, I think, was partly owing to the lime with which the nuts had been ſprinkled, and partly to their being ſo much dried, that in many places they were cracked in the inſide. In this my ſearch, however, after diſſecting many nuts, I at length, with great pleaſure, not only diſcovered the plant, but ſucceeded in taking it out of the nut. The outer part of the leaves of this plant was formed with many indentings and points in the manner of vine leaves, and the leaves themſelves were as large as I ever found in the ſeed of any tree whatever. Upon viewing theſe leaves by the microſcope, I could ſee the veins or veſſels, lying in as regular order, as are to be ſeen by the naked eye in the full grown leaf of any tree.

Fig. 2, KLMN, repreſents this ſmall plant taken out of the Nutmeg, as nearly as the limner was able to draw it from the naked eye; and though it ſeems to be compoſed of many leaves, yet, in my judgment, there are but two; but I could not examine that matter very accurately, becauſe in the attempt, the plant was often broken. The part in this figure marked N is that, from whence the ſtem and root would grow.

Moreover, I placed a ſmall piece of the outward part of this leaf before a microſcope, and directed the limner to make a drawing of it with all the veſſels in it, as they appeared to him.

Fig. 3, OPQRS, repreſents this piece of leaf; OP, is the part which was broken off from the reſt of the leaf, and QR is the external edge of it.

In this ſmall piece of leaf we not only ſee, how the veſſels or veins are branched out into ſmaller ramifications, but in many places may plainly be ſeen, the oily matter or ſubſtance, which is the ſame in nature and colour, as is to be ſeen in the nut itſelf. And ſince we ſee ſo many branchings of the veins in ſo ſmall a piece of a leaf, who can tell how many more ramifications there may be in it, entirely eſcaping our ſight?

During the time that I was employed in ſearching for the plant in the Nutmeg, I fell into converſation with a friend reſpecting the tree that bears this fruit, which tree, I was perſuaded, had ſome cavity in the middle of it; this coming to the ears of a certain Profeſſor, he ſent me two pieces of the root of the Nutmeg tree.

Upon examining thoſe pieces of root, both at the larger and ſmaller ends, I was greatly ſurprized to find, that this wood is of a remarkably ſpongy nature and very porous, though it has not any cavity in it, different from the wood of other trees; for, from the root, we muſt conclude, that the tree itſelf is of the like formation.

And in this root, I perceived ſome wonderfully minute veſſels, ſurrounding, as it in were, many places, the larger tubes of the wood, and through which, as I ſuppoſe, the tree receives nouriſhment in its growth.

In order, as exactly as poſſible, to exhibit to view the wood, or rather the root of the Nutmeg-tree, which bears ſuch a precious and highly valued fruit, I have given the figure of a circle, which we muſt ſuppoſe to be a branch of the tree, or of its root, ſawed off tranſverſely, as is to be ſeen at *fig.* 4, ABCDEF. From the center of this figure are drawn many very ſmall lines, as appears between CDFA, and theſe we are to ſuppoſe are thoſe veſſels which ſerve for the increaſe of the tree or root, and, by means of which, there is every year a new ſubſtance formed about the tree, as I have often heretofore mentioned.

Now, in order to inveſtigate accurately, the true formation of this wood, we muſt not examine merely the extremity of it, which would preſent an obſcure object to the eye, but we muſt cut off a ſmall piece or particle of the wood, as from E to the circumference, after we have, with a very thin and ſharp knife, cut or pared the extremity as ſmooth as poſſible. In this manner I cut off a piece or particle of the wood, not ſo large as is ſhewn at *fig.* 5. This piece of wood, placed before the microſcope, and copied as exactly as the limner was able to repreſent it in his drawing, is ſhewn at *fig.* 6, ABCDEFGH, and in it are to be ſeen, many of the veſſels or tubes of which the wood conſiſts, ſome of the larger ones of which, I have exhibited at I, I, I.

Among theſe larger tubes of the wood are to be ſeen a great number of ſmaller ones, and many of theſe ſmaller tubes are again ſurrounded by other exceſſively minute veſſels, through which latter veſſels, for the moſt part, the nouriſhment is conveyed upwards in the tree, as I ſuppoſe.

But, as theſe ſmaller veſſels, which are plainly to be ſeen by the microſcope, cannot, by reaſon of their minuteneſs be well expreſſed in a drawing, unleſs ſtill more enlarged, I uſed a microſcope of greater magnifying power, and cauſed a ſmall portion of the wood which in *fig.* 6, is ſituated between the two larger veſſels, K and L, to be drawn ſomewhat larger than it appeared through the microſcope before which it was placed, and this is ſhewn in *fig.* 7. ABCD.

This piece of wood was ſo cut, that all the horizontal veſſels were exactly divided, and I could plainly perceive them, whether I viewed the object upwards or downwards; and I further ſaw, that where the horizontal veſſels lay, there the larger tubes of the wood were ſituated, as appears in this figure at AB, and DC, which is where the horizontal veſſels were ſituated.

In *fig.* 6, are alſo ſhewn, the horizontal veſſels which take their courſe among the perpendicular veſſels or tubes of the wood, but, as all the aſcending veſſels or tubes are cut tranſverſely, ſo that their cavities become conſpicuous, on the contrary, the horizontal veſſels, by this manner of cutting, preſerve their ſhape as near as may be. In this figure there appear more of theſe laſt veſſels about the parts marked A and B, than about G, or between G and F; the reaſon of which is, that in ſplitting the wood, the knife did not paſs in ſo ſtraight a direction along thoſe veſſels as I wiſhed: for the ſame reaſon theſe horizontal veſſels appear in greater numbers at E, or between E and F, than about C.

In theſe horizontal veſſels may be ſeen a red and yellowiſh ſubſtance, ſimilar to the oily matter in the Nutmeg, and the young plant it contains, ſo that the horizontal veſſels are of a reddiſh colour.

Farther, I determined to cut theſe horizontal veſſels, each of which can be diſtinctly ſeen, and which generally lie three, or at the moſt, four together in rows, in an oblique manner, ſo as to exhibit their cavities to view. A ſmall particle of the wood repreſented at *fig.* 4.

ABCDF, ſplit lengthwiſe, at the part marked DF, I placed before a microſcope, and this very thin particle, ſo ſplit off, is ſhewn at *fig.* 8, PQRS, in which appear eight diſtinct places, where the horizontal veſſels are cut in this oblique manner, as may be ſeen by the cavities in many of them, a part of which is ſhewn at Q.

The perpendicular aſcending veſſels, *fig.* 8, PS, or QR, are thoſe ſmall veſſels, which in *fig.* 6, between K and L are ſhewn cut obliquely.

Moreover, I ſplit this branch of wood in the middle, as the line ABC in *fig.* 4 denotes, and from the piece ſo ſplit, I cut a ſmall particle, dividing the horizontal veſſels longitudinally. This particle of wood is repreſented at *fig.* 9, TVWXYZAB, where TV, and YZ, are the aſcending veſſels, and the horizontal veſſels which croſs them, are ſhewn at WX and AB: and in, and among theſe horizontal veſſels we ſaw various minute globules, which the limner, as nearly as he was able, imitated in the drawing.

In my obſervations on this wood, I ſaw four ſeveral kinds of woody tubes, beſides other ſmaller ones, which, by reaſon of their minuteneſs, as I judged, could not be diſtinctly ſeen; but thoſe which could be diſtinguiſhed I cauſed to be drawn.

Fig. 10, CD, repreſents a tube of the wood partly compoſed of annular parts, like a wire wound round a pin; and, next this a tube formed in a different manner, ſeeming to conſiſt of a pellucid membrane, covered with many ſmall dots or ſpecks, which in ſeveral places were contiguous to each other; this tube is repreſented in *fig.* 10, at EE.

Fig. 11, GH, repreſents a third tube of the wood, covered with ſmaller ſpecks or dots, but, what is more remarkable, it contains in this ſmall ſpace five joints, very much like thoſe of which ſtraw is compoſed: two of theſe joints are repreſented at G and H.

I endeavoured alſo, if poſſible, to diſcover the formation of the larger tubes, ſhewn in *fig.* 6, at I, I, K, L, and while I was thus

employed, it appeared to me, that the tranſparent membrane conſtitutiug the tube, was compoſed of veſſels taking their courſe round about the tube.

To make proof of this, I tore ſome of theſe tubes of the wood aſunder longitudinally, when I perceived, that where torn, they were very much indented or jagged, whence I concluded, that however tranſparent they might appear to me, they were yet compoſed of a great number of veſſels lying in a circular direction.

Fig. 12, I K, repreſents a part of one of thoſe larger tubes ſo torn and jagged, which is very cloſely united to the adjoining ſmall veſſel at L M in the ſame figure, and from which, as I think, this larger tube received nouriſhment in its growth, and the rather becauſe, though the membrane or coat of this tube appeared tranſparent, yet it plainly appeared, that the membrane was compoſed of minute veſſels, which appeared to derive their origin from that ſmall veſſel.

I then proceeded to examine theſe larger tubes of the wood, with all the accuracy I was able, and I was well aſſured, that I ſaw the membrane compoſing them to be made of veſſels like ſtreaks croſſing each other at right angles; a particle of this membrane is ſhewn in *fg.* 12, at L N O I, where the veſſels or ſtreaks from I to N and from L to O mutually croſs each other, by which means this thin ſubſtance is ſtrengthened; and who can tell how many, and what various parts ſuch a tube of the wood may contain?

I think I have formerly ſaid, reſpecting the veins in the leaves of trees, that they are of a ſpiral twiſted form, like that repreſented in *fig.* 10 at C D; and alſo, that the ſtring by which many nuts (as the filberd, almond, &c.) have nouriſhment conveyed to them through the hard ſhells, conſiſts of many veſſels of the like kind, and upon recollecting this I determined, as far as I was able, to diſſect the young plant I had taken out of the Nutmeg, to ſee whether the veſſels repreſented in *fig.* 10, at C D and which are in great numbers in the wood, could alſo be found in the young plant.

For this purpoſe, I firſt examined the leaf of the young plant, in that part where it was ſo thick as to be opake, and immediately I ſaw in it three diſtinct veſſels of the like ſpiral or twiſted form, as I have before mentioned to have ſeen in the root. This enquiry I proſecuted as far as the extremity of the leaf, where I ſaw a ſmall veſſel of the like kind, and ſo diſtinctly, that I could count every ſingle fold or ſpiral turning in it.

Since it now appears plain to us, that provident Nature forms all the veſſels of this tree in ſo perfect a manner, that the ſmall ones in a young plant in the ſeed, are as plainly to be ſeen as thoſe in the wood at full growth, which we may juſtly conclude is the caſe in all ſeeds, however minute ; we are not to wonder that the ſmalleſt of any animal which we view by the microſcope, is as completely provided with all its parts as when it is grown larger. In a word, the farther we endeavour to dive into the hidden works of Nature, the more we ought to be convinced, that we never can arrive at her fartheſt receſſes, though many perſons, when making uſe of a good microſcope, weakly ſuppoſe, that nothing is out of the reach of their obſervation.

On damaged Mace, commonly called white Mace; the cauſe from whence this defect ariſes, ſhewn to be an inſect which feeds on the internal parts of the Mace, with a particular deſcription of that inſect; and ſome farther account of the Nutmeg.

UPON hearing formerly, mention made of that ſort of Mace which is denominated white Mace, I merely thought, that it was not ſo good either in flavour or virtue as the reddiſh-coloured Mace, and the rather, as I long ago heard that a certain phyſician had the art to give the white Mace the ſame colour as the beſt; but having been ſince informed that this white Mace had ſo little virtue, that it was ſorted from the reſt and burnt, and hearing that its inferiority was ſuppoſed to proceed from ſome defect or want of nouriſhment in the growth of the plant, I had a great deſire to examine the nature of this white Mace.

On converſing upon this ſubject with one of the Directors of our Eaſt India Company, he informed me of the time when the officers at the Company's warehouſe, were employed to ſort out the white Mace, and gave me permiſſion to go to the warehouſe and ſatisfy my curioſity in this reſpect. I accordingly attended at the warehouſe, and perceived, not without ſurprize, that the white Mace was compoſed of nothing but thin membranes or ſkins, and I alſo obſerved a kind of webs, which I concluded had been ſpun by ſome inſect, which webs were fixed to ſome of the Mace, not only the ſound, but alſo the damaged. I brought home with me eight or ten of theſe webs, and found them to be covered in part

with certain oblong black particles, which I concluded to be the excrements of the maggots, by which thoſe webs had been ſpun: in ſeveral of theſe webs, I alſo ſaw certain particles which ſeemed to be the fragments of aurelias, from which ſome ſpecies of flying inſect had proceeded, and, as in one of theſe webs I perceived ſeveral minute feathers, very much like thoſe found on the wings of moths, I further concluded, that the flying inſects which proceeded from theſe webs muſt bear ſome reſemblance to the moths in this country.

In order to ſatisfy myſelf further, I went the next day to the Company's warehouſe, and ſpent a whole hour with ſome of the officers in ſearch of theſe webs, and at the ſame time, the officers gave me a leaf or piece of Mace very much ſhrivelled, in which was the apperance of a web, and on opening the leaf, I found in it a white flying inſect, (which was not only dead, but had loſt ſome of its legs,) in ſhape and ſize not unlike thoſe white moths that are found in granaries, and from whoſe eggs proceeds the maggot called the wolf,* though I judged this inſect to be of a different ſpecies. Upon my return home, I examined all the webs I had found, and in ſeveral of them, diſcovered the ſkins or caſes of aurelias, from which flying inſects had proceeded, and in two of them; the inſects themſelves; I alſo found one perfect cryſalis, and in it the inſect dead; and upon attentively examining this cryſalis, I plainly perceived that it was exactly of the ſame ſhape and nature with all the other ſkins of aurelias which I had found. I cauſed a drawing to be made of this aurelia or cryſalis of the ſame ſize it appeared to the naked eye; this is ſhewn at figure 13, AB, in which the reſemblance is taken as accurately as the limner could imitate it in his drawing.

Fig. 14, CD repreſents the flying inſect which proceeded from one of theſe aurelias; the wings of which, would I believe, have appeared longer than here repreſented, had not the animal while

* The deſcription of this inſect is to be ſeen at page 25.

ſtruggling to get out from amongſt the Mace where it was encloſed, broken off part of them, in which ſtruggle alſo, I fancy it had been killed.

After this, I applied myſelf to examine the white Mace, as it is called, a parcel of which I had brought home with me; and I immediately perceived that all the matter or ſubſtance which had been encloſed between the membranes compoſing the outward ſurface of the Mace, was conſumed or eaten away. This ſubſtance, which for the moſt part, conſiſts of oily globules, in which the whole virtue of the Mace conſiſts, being ſo ſtripped from thoſe membranes (of which membranes, the leaves of all plants, however ſmall they be, are compoſed, and whereby the internal moiſture of the leaf is kept from evaporation) nothing remains but the thin membranes themſelves, conſiſting of wonderfully minute veſſels, lying lengthwiſe in the leaf, which altogether exhibit a white appearance: hence theſe leaves are called white leaves, or white flowers of Mace, whereas, in fact they are nothing but the very thin membranes of thoſe leaves.

I found, on the inſide of theſe membranes, various oblong particles pointed at the ends, and ſome of them tranſparent; theſe I concluded to be the excrements of the maggots I have mentioned, and to have been voided by them at different periods of their growth, becauſe, though of different ſizes, theſe particles were all of the ſame ſhape. Farther, I obſerved ſome of the broader leaves of Mace to be ſo eaten away, that only one of the membranes remained, and having in vain ſought among them for any animalcule, I threw them all away.

After this, I procured a freſh ſupply of the white leaves of Mace, not doubting that I ſhould find ſome dead animals among them. At length, after a long ſearch, I found a ſmall white particle, not larger than a grain of ſand, which, examining by the microſcope, I found to be an animalcule, the hind part of whoſe body was tranſ-

parent and oblong, but the fore part was covered with ſome extraneous matter, which endeavouring to wipe away, I broke it off from the hind part.

I was, however, hereby induced to make a further ſearch, not doubting, that I ſhould find ſome of theſe inſects of a large ſize, but I could not diſcover any of them among the leaves whoſe membranes were entirely ſtripped of their contents; whence I concluded, that the maggots, when grown large, had either quitted the leaves or undergone a change in their form, whereupon I ſat about examining thoſe white leaves which lay next the others that were found, as alſo thoſe leaves which were in great part, but not wholly, conſumed; ſix or ſeven of which I had brought with me; and among theſe, I found a few animalcules of the ſame ſhape with the one I laſt mentioned; theſe were not only larger than the former, but their bodies were of a reddiſh colour, and I judged that this colour proceeded from their feeding on the oily matter, of which the Mace, for the greateſt part conſiſts, and that the former tranſparent animal had died before it had fed on that coloured ſubſtance.

At *fig.* 15, is ſhewn one of theſe maggots, of the ſame ſize as it appeared to the naked eye; this was one of the largeſt that I had met with in my ſearch.

The diſcovery of theſe maggots very much excited my admiration, becauſe I had never ſeen any thing like them in the Nutmeg, and the more, becauſe theſe maggots feed and ſubſiſt on the oil in the Mace, of which oil the Nutmegs are alſo in part compoſed. But the reaſon why thoſe animalcules, which ſeek their food in the Nutmeg are not found in the Mace, is, in my opinion this, that thoſe which devour the Nutmeg avoid the oily matter it contains and only feed on thoſe parts of the nut where there is little or none of that oil.

Having thus diſcovered the maggots (deſcribed in *fig.* 16,) which feed on that thin matter or ſubſtance found within the membranes of

the Mace, and which afterwards quit the Mace, leaving the membranes themſelves unhurt, except in that part where they firſt gained admittance; I cauſed a drawing to be made of ſome of theſe Mace leaves, a part of which is of that ſort called white Mace.

Fig. 16, A B K C D E, exhibits part of a leaf of Mace, and in this figure, between E F G and H, may be ſeen the ſtripes of the leaf, which are engraved with very light touches, ſo as to give the appearance of white; theſe are the parts called white Mace, and from them the oily ſubſtance is all conſumed, leaving only the bare membranes. Now, if this whiteneſs had been cauſed by the want of nouriſhment in the plant, then the extremities of the leaves at C or D, would have been white alſo, whereas, on the contrary, they were of the proper colour, and of a good flavour, by reaſon that the maggots had not eaten away the oil from within the membranes farther than where the leaves appeared white.

Lower down, in the figure, between G and H, may be ſeen a ſmall hole made in the membrane of the leaf, which I conclude, was bitten by the maggot, to open for itſelf a paſſage into the leaf, and the rather, becauſe the thin membranes in this part of the leaf were entirely unhurt, nor did there appear any perforation in them, except in the before mentioned place towards A B. And, if we conſider the narrowneſs of the cavity in theſe white leaves, where the oil is eaten away, we may conclude, that it muſt have been an exceeding minute creature which could turn itſelf about in ſo ſmall a ſpace, and then procure its ſubſiſtence; and, between the membranes in this part of the leaf, I found nothing, except the excrements of the maggot.

When I was endeavouring, ſome time ſince, to diſcover the young plant in the Nutmeg, I alſo tried to find out, in what manner the nut, while incloſed in its ſhell, received nouriſhment from the tree; and for that purpoſe, I took a Nutmeg which was preſerved in ſugar,

dead flying inſect, of the ſame ſpecies with thoſe, many of which I have mentioned to have found in the Nutmeg. Upon breaking open one of theſe nuts, I ſaw, that all the internal whitiſh ſubſtance of it, where there had been little of the oil, was eaten away, and nothing left in the cavity except the excrements of the maggot, and the web it had ſpun while in that place; but, as I did not find any ſkin or remnant of an aurelia, I judged that the maggot, not finding a ſufficient quantity of ſuſtenance in this nut, had quitted it before it arrived at its full growth. On this occaſion, I could not but admire the inſtinct which teaches theſe inſects to perforate the hard ſhell of the Nutmegs, and for that purpoſe, to find out that part in it which is ſofter than the reſt; for this I found to be the caſe not merely in one or two inſtances, but in as many as ten Nutmegs, I obſerved the ſame.

Fig. 17, L M N, repreſents the Nutmeg incloſed in its ſhell, and covered with the leaves of Mace, but which coverings are, in India ſtripped off while freſh and green. All theſe receive their growth and increaſe through the part between L and M, which is the place where the nut adjoins to the tree; and I at firſt thought, that the Nutmeg was nouriſhed from its ſhell or bark, as I had obſerved was the caſe with the walnut; but upon a more careful inveſtigation, and after cutting open the ſhell with a fine ſaw, I found, that I had been miſtaken herein, for I could not diſcover any thing at the part marked L M, which had the appearance of having tranſmitted nouriſhment to the fruit. I ſoon, however, perceived two places adjoining to each other, one, as I concluded, for the nouriſhment of the bark, and the other of the nut itſelf; and, on further ſearching, I ſaw, that the veſſels deſtined for this purpoſe, did not immediately enter the nut at that point, as I had obſerved in filberts, almonds, and other ſeeds, but that the veſſels in this nut take a courſe from M in *fig.* 17 to the point of the nut at N, and there paſs through the

ſhell, and by this means, the nut receives its nouriſhment; for it is not united to its ſhell in any other place.

To exhibit this to the eye, I cauſed a drawing to be made of the bark or ſhell containing the Nutmeg, after the leaves of Mace had been ſtripped off, and having alſo firſt looſened from it the ſtring through the veſſels in which nouriſhment is conveyed, leaving only the ſtring affixed to the part where it enters through the bark, to ſhew more plainly the place where the nut receives its nouriſhment.

Fig. 18, O P Q, repreſents the bark or ſhell wherein the Nutmeg is incloſed; Q R, is the ſtring, conſiſting of multitudes of veſſels which convey nouriſhment to the nut; O and Q exhibit the furrow or creaſe wherein the ſtring lay before it was pulled out. This ſtring I cut into very thin ſlices, ſome of which I placed before the microſcope, that I might the better diſcern the great number of veſſels in them, of which I cauſed a drawing to be made, as nearly as they could be diſtinguiſhed and repreſented. This is ſhewn in *fg.* 19, A B C D E, being one of the ſlices I have mentioned, cut obliquely, and magnified.

Now, if we contemplate the incredible number of veſſels in ſo ſmall a ſtring, (for that which in *fig.* 18 is ſhewn at Q R, is, in reality twice the ſize of the real ſtring, becauſe I did not ſtrip it of the ſkin which covered it, leſt I ſhould injure the veſſels it contained) beſides thoſe which the ſight cannot reach, we muſt conclude, and be aſſured, that there is not a veſſel in a full grown Nutmeg tree, for whatever uſe it may be deſtined, but there is a ſimilar one in this ſtring; otherwiſe it could not communicate to the young plant in the Nutmeg, all the veſſels requiſite for the formation of the future tree and fruit.

In a word, the inconceivable perfections which are contained in theſe ſtrings of plants, and conſequently in every ſeed, are to us incomprehenſible, and, ſtill more, inſcrutable.

Plate III.

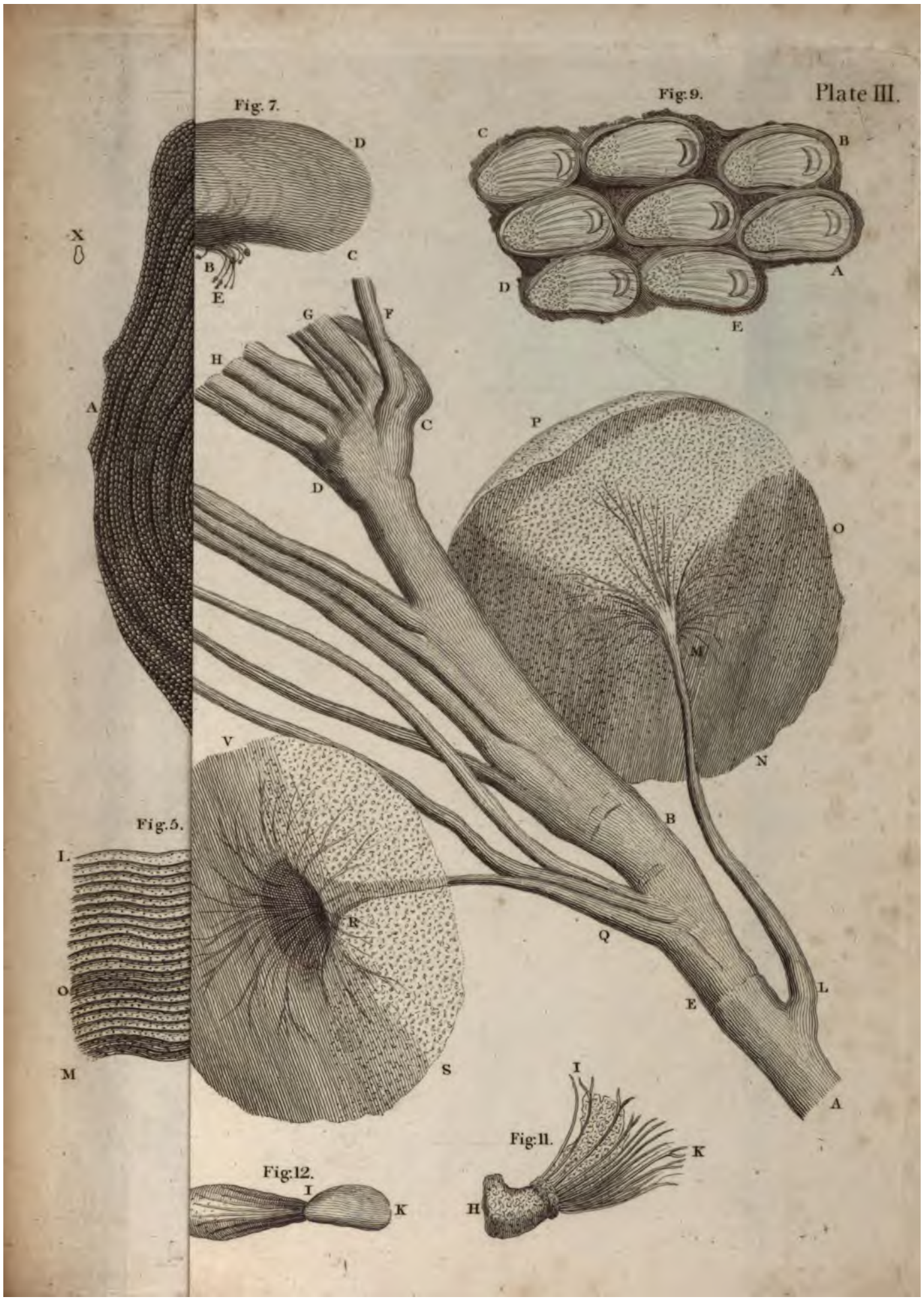


Fig. 7.
X
D
C
B
E
A
Fig. 9.
C
B
D
A
E
G
F
H
C
D
A
P
O
M
N
B
Q
L
E
V
R
S
Fig. 5.
I.
O
M
Fig. 11.
I
K
H
Fig. 12.
I
K

Plate V

Fig. 7
B
A
C
M
O
N
C
L
D
X
K
Fig. 14
Q
O
R
Fig. 17
E
B
A
18
N
L
Fig. 25
A
Fig. 8
a
a
a
a
T
S
R
V
Q
Fig 15
S
T
P
Fig. 16

account of their feeding on the Nutmeg, as by laying their eggs, the maggots proceeding from which, muſt be exceedingly pernicious, becauſe they acquire their whole growth within the nut.

I am perſuaded, that if the timber and wood in warehouſes was painted with the common red paint uſed in this country, the ſpices might be preſerved from many noxious inſects, becauſe the particles of that paint, though ground very fine, are of ſo hard a nature, that no ſmall inſect can penetrate them. And if the wood is obſerved to be perforated with many worm-holes, the painting ſhould be repeated until all thoſe holes are ſtopped up with it.

It may be ſaid indeed, that Nutmegs and Mace are kept but a ſhort time in the warehouſes, and therefore not liable to be much injured; but in that ſhort time, and while expoſed to dry, they may be infected by theſe flying inſects laying their eggs among them; and it is well known, that many of theſe creatures lay many eggs in a very little time. Indeed, if Nutmegs and Mace are kept in large heaps in the warehouſes, I believe that only the ſurface of them might be expoſed to injury, becauſe the inſects cannot penetrate far into the heaps to lay their eggs, and therefore the middle of theſe heaps may be uninjured.

But theſe matters are all conjecture, and, as it were, riddles to us at this diſtance, reſpecting which, thoſe who are employed upon the ſpot, in collecting or drying the ſpices, could give much better information, if they were perſons of intelligence and obſervation.

To return to the inſects which I found among the Mace; I was doubtful how to purſue my enquiry reſpecting the generation of theſe creatures, and the rather, becauſe thoſe which I found, were not only dead, but their bodies very much dried, for, had they been living, I doubt not, that I ſhould eaſily have diſcovered the manner in which their ſpecies is propagated.

At length, upon conſidering the ſhape and make of theſe mag-

Plate VI.

Fig. 4.

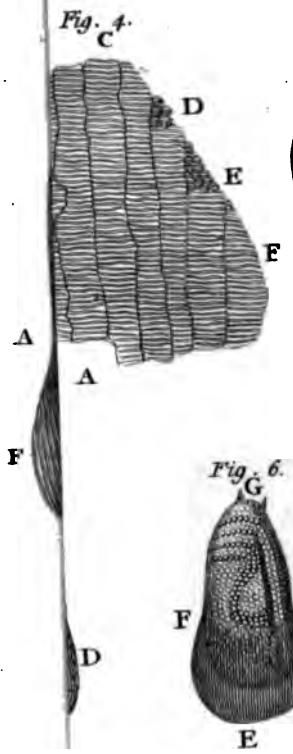


Fig. 6.

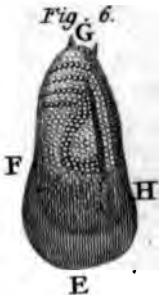


Fig 7

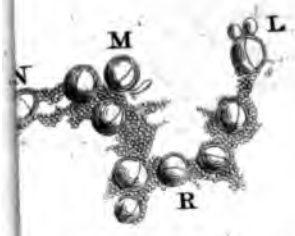


Fig. 17.

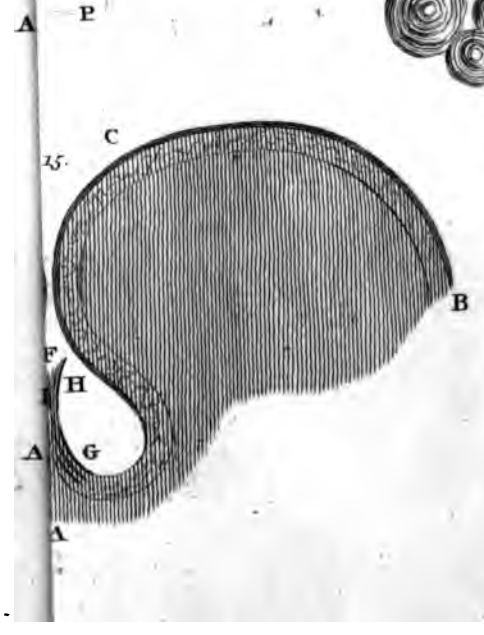
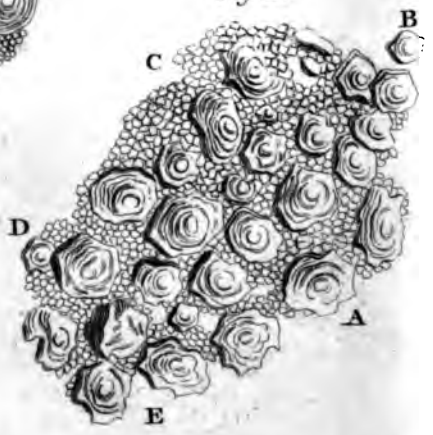


Fig. 18.



a much ſofter nature, they may then multiply much faſter than thoſe which breed in wood, and eſpecially in the harder ſorts.

I placed one of theſe creatures, changed from the maggot into a flying inſect, before the microſcope, and having removed the ſhields or caſes of its wings a little aſide, in like manner as if the animal was living and about to take its flight, I beheld ſo wonderful a piece of workmanſhip, wrought with ſuch curious art, that I determined to have a drawing made of it, though it was impoſſible to delineate all the wonders that were diſplayed in this minute animal.

Fig. 24, ABCDEFGHIKL, exhibits this flying animal, which appeared longer than the maggot from which it was produced, the reaſon of which I take to be, that the bodies of theſe maggots being very ſoft, they contract when their moiſture evaporates, whereas when changed into flying animals their bodies are hard on the outſide, and therefore cannot contract.

LM, and BN, are the two horns made with many joints and covered with hairs.

L, B, are the eyes compoſed of various optical organs, though but few in compariſon of thoſe which are found in the eyes of flies.

This creature has ſix feet, each furniſhed with two curiouſly made little claws; the legs are made with various joints at the extremities, and are covered with hairs, or rather with pointed particles like thoſe on brambles: two of theſe legs with their claws, are ſhewn at C O and D P.

At DI and KI are pictured the two ſhields, or caſes, with which the animal, when not in the act of flying, can cover the hind part of its body, ſo that I conclude, no particles of the wood, or of the Mace, nor any drops of water which may accidentally fall on its body, can injure the wings.

Upon attentively contemplating theſe ſhields or caſes, I was

Now, as all caterpillars, maggots, and other ſmall animals when changed into flying inſects do ſtill preſerve the ſame ſort of creaſes, rings, or diviſions, which they originally had, ſo I perceived in the flying animal, produced from theſe maggots, the ſame kind of rings or diviſions, but theſe did not become conſpicuous till the two ſhells, or caſes which covered the hind part of the body were removed: under theſe caſes lie two exceeding ſmall wings folded together, and by reaſon of their being longer than the body, doubled up: ſo that it ſeems probable to me, that theſe creatures are formed in the ſame manner as inſects of the beetle kind, with regard to their wings, and the caſes that cover them.

If we reflect on the nature of thoſe flying animals, whoſe wings are thus folded up and covered with ſhields or caſes, and who are deſtined to ſeek their food in hard ſubſtances, ſuch as wood, nuts, and the like, or who are hatched in the earth, we ſhall ſee the neceſſity of their wings being formed in that manner, for if the wings were not longer than the hind parts of their bodies, they would be too ſmall for flight, and if not defended by the caſes or ſhields, they would be liable, when the animals are creeping into holes either in the earth or in the hard ſubſtances on which they feed, to be ſo broken or injured, as to be unfit for the purpoſe of bearing them through the air.

Theſe animals, even after they are converted into flying inſects, do, in my opinion, take food, contrary to what is obſerved in the moths or butterflies produced from ſilk-worms and caterpillars, for I obſerved, that ſome of theſe were of a bright and others of a dark red, the former of which, I ſuppoſe, had not been long changed, and therefore had not taken ſo much food as the latter.

I have often thought, that perhaps, theſe kinds of animals may feed upon wood, but, that when they get among Mace, which is of

wing. QR is the muſcular part, by means of which, not only the wing is put in motion, but doubtleſs many leſſer muſcles are derived from this, by means of which, that part of the wing at WXY is extended in length, and the part at YQ expanded in breadth: at ST is the minute wing I mentioned above.

When we duly conſider this moſt perfect workmanſhip of the Divine Artiſt, we muſt confeſs, that thoſe things which we diſcover by our microſcopes and induſtry, are but as the ſhadow of thoſe which hitherto remain concealed from us, not only in ſuch ſmall animals as this now under conſideration, but alſo in larger animals, and in plants.

It is to be hoped then, that the enquirers into Nature's works, by ſearching deeper and deeper into her hidden myſteries, will more and more place the diſcoveries of thoſe truths before the eyes of all, ſo as to produce an averſion to the errors of former times, which all thoſe who love the truth, ought diligently to aim at. For,

We cannot in any better manner, glorify the Lord and Creator of the Univerſe, than that, in all things, how ſmall ſoever they appear to our naked eyes, but which yet have received the gift of life, and power of increaſe, we contemplate the diſplay of his Omniſcience and Perfections with the utmoſt admiration.

END OF THE FIRST VOLUME.

SIDNEY,—PRINTER, BLACK HORSE COURT, FLEET-STREET.

Plate VIII.

Fig. 4.

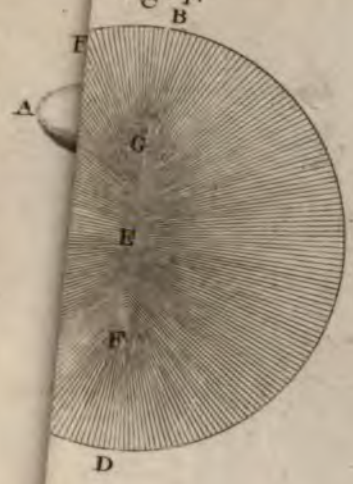


Fig. 6.

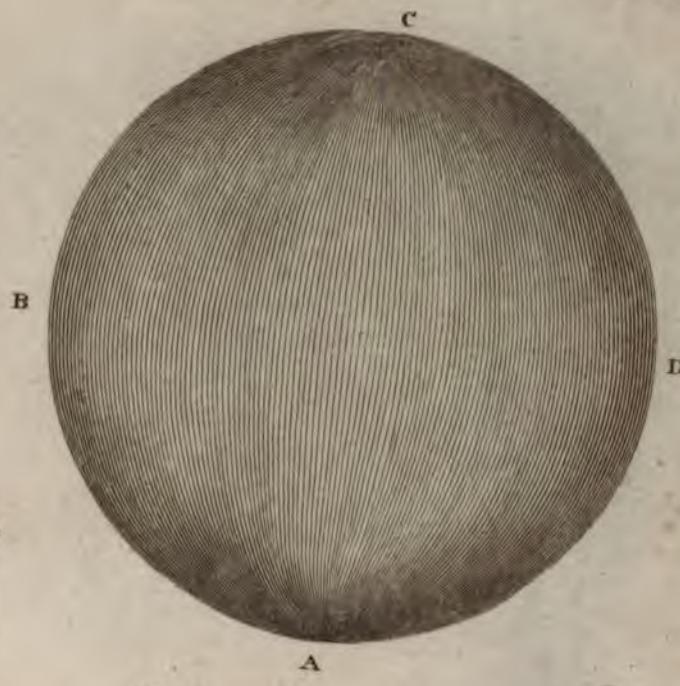


Fig 7

Fig. 8.

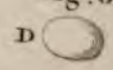


Fig. 9.

X

Fig. 15.

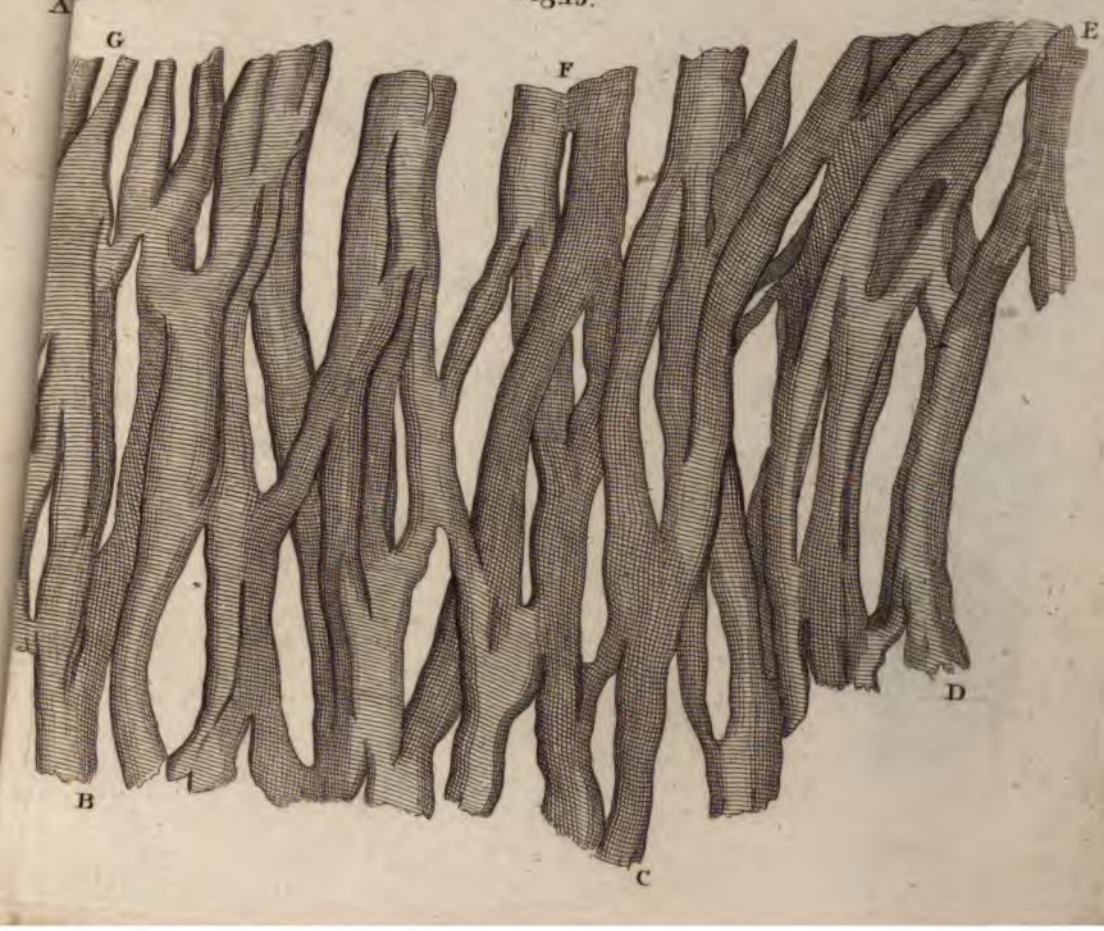


Plate IX

Fig. 1

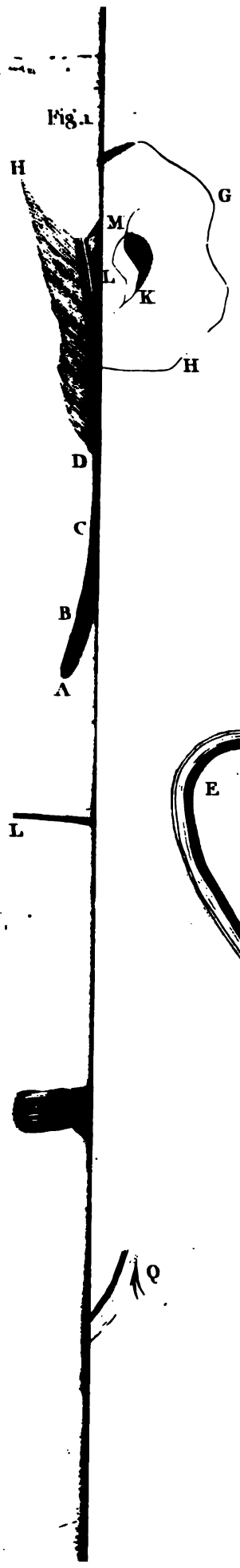


Fig. 7

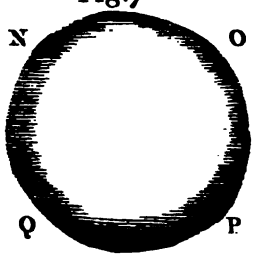


Fig. 8

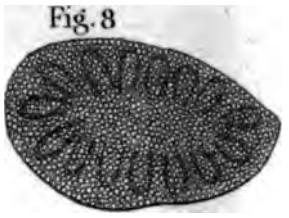


Fig. 10

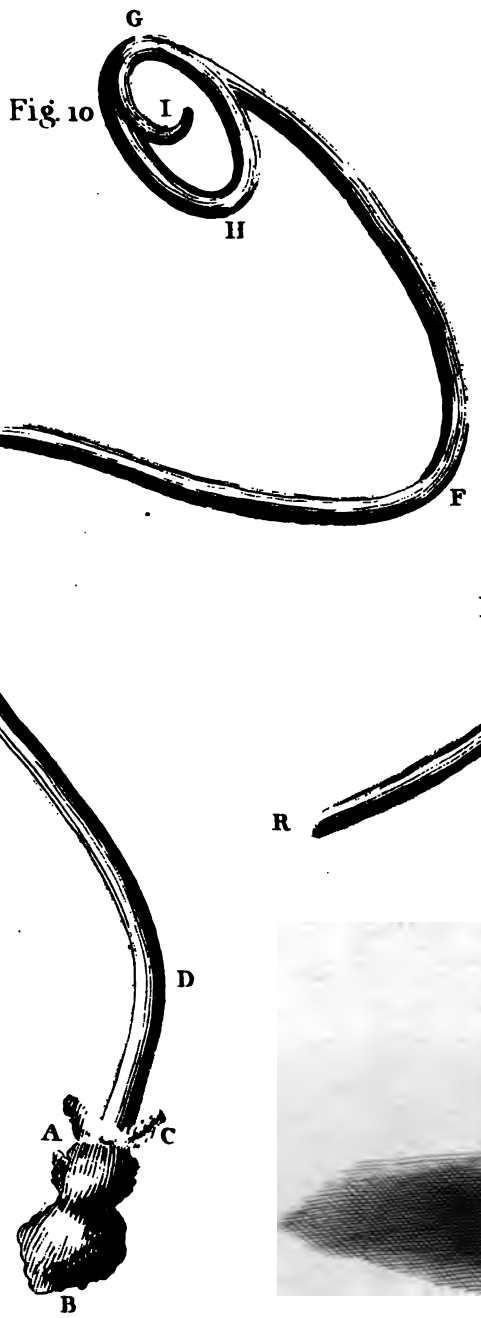


Fig. 14

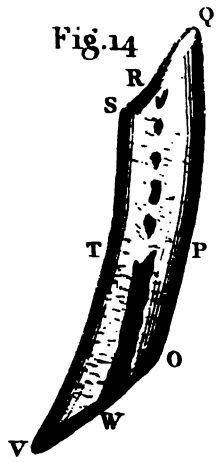


Fig. 13

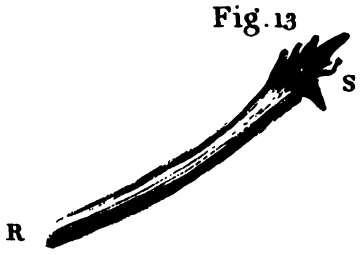


Fig. 17

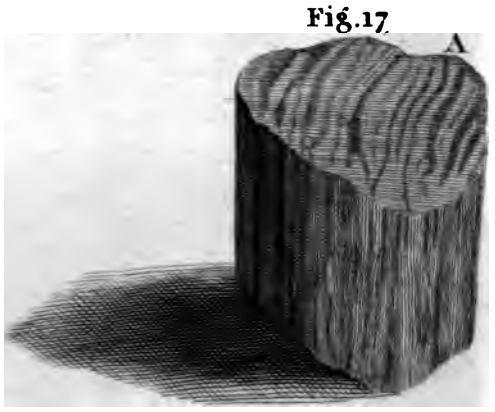
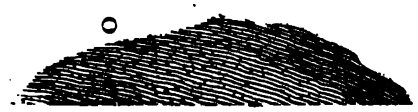
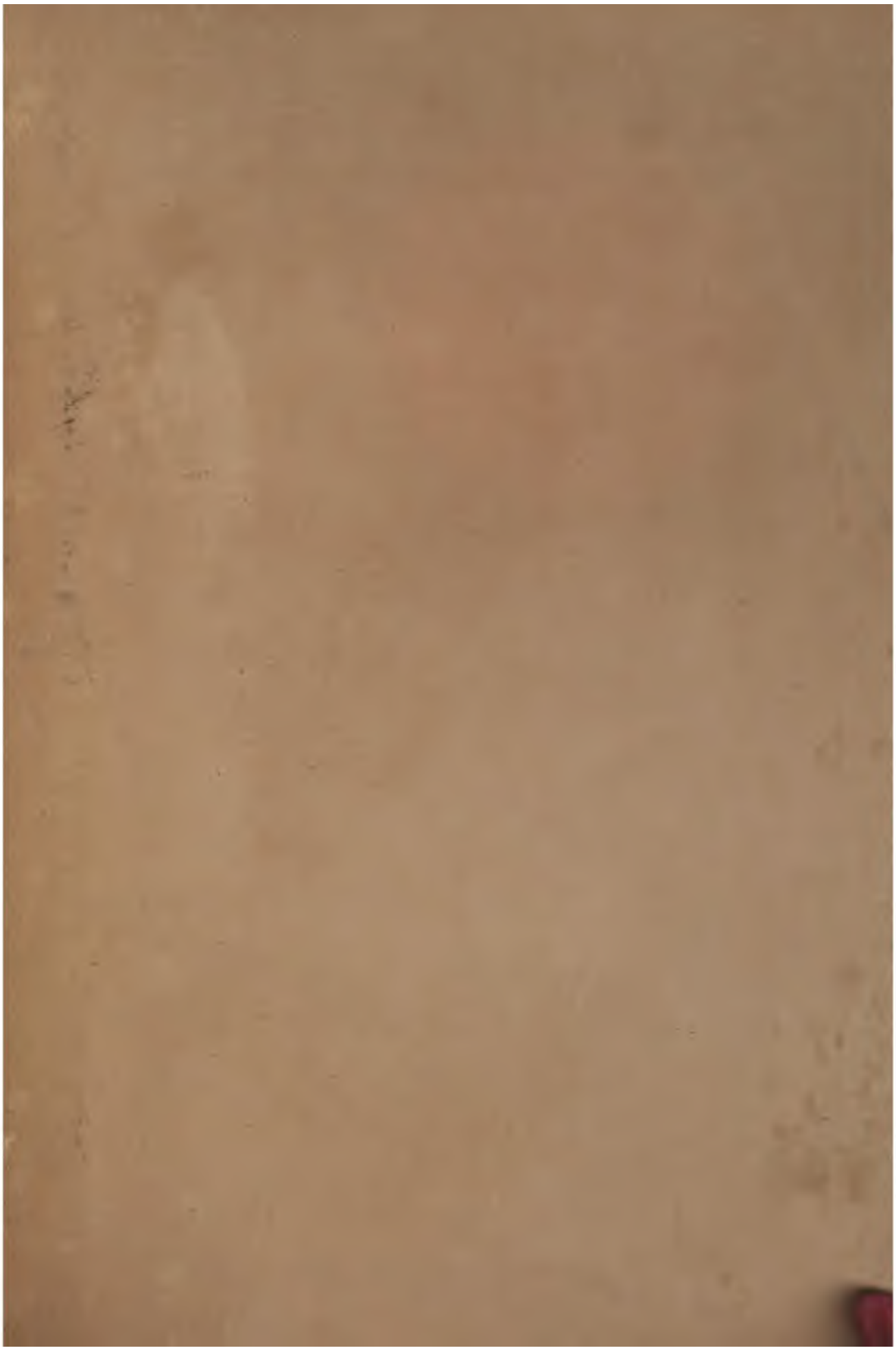


Plate III.





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